NAT. RES. COUNCIL. COMM. on MARINE Ecology--
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REPORT OF THE COMMITTEE ON MARINE ECOLOGY AS RELATED TO PALEONTOLOGY

1945 - 1946

HARRY S. LADD, CHAIRMAN

Division of Geology and Geography
National Research Council
Washington, D. C.

NATIONAL RESEARCH COUNCIL
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DIVISION OF GEOLOGY AND GEOGRAPHY

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* REPORT OF THE COMMITTEE ON MARINE ECOLOGY AS RELATED TO PALEONTOLOGY

1945-1946

Appendix G of Annual Report
of the Division for 1945-46

* (No. 6 in this Series)

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REPORT OF THE COMMITTEE ON

MARINE ECOLOGY AS RELATED TO PALEONTOLOGY

INTRODUCTION

No formal meetings of the Committee have been held since June 6, 1945 but the members have kept in touch by correspondence, there have been numerous conferences between members resident in Washington, and the Chairman has visited several of the members outside of Washington. Following recommendations made in a Preliminary Report submitted in April 1946, three new members were appointed to the Committee:

Dr. K. O. Emery, University of Southern California, Los Angeles
Mr. A. W. B. Powell, Auckland Museum, Auckland, New Zealand
Lt. Col. H. G. Schenck, Natural Resources Section, SCAP, Tokyo.

K. E. Lohman has been appointed Vice-Chairman of the Committee and one member, H. C. Stetson, has resigned because of the pressure of other duties. The new members have assisted in the preparation of the annual report.

The present report is the longest that has been issued by the Committee but it is anticipated that future reports will be shorter. Chief reason for the length of the present report is the inclusion of four papers made up largely of annotated references dealing with Pacific ecology and paleoecology. Each of these papers contains material that will be used in preparing annotated bibliographies for the proposed Treatise. It has seemed desirable to make them available in their present form because of the current and widespread interest in the Pacific area.

The present report also contains three short contributions. One of these is an original contribution by Dr. Hiroshi Niino of the Tokyo College of Fisheries dealing with the distribution of organisms in a part of the Japan Sea. It is believed that many will be interested in the kind of work that Dr. Niino has been doing and it is expected that a fuller account of his studies will be published elsewhere later on. The final article in this year's report is a rather lengthy one by Preston Cloud and Virgil Barnes on the paleoecology of an area in Texas during early Ordovician time. This article discusses many of the problems that were considered by Dr. J. S. Cullison in last year's report (No. 5, pp. 47-53, 1945). The Cloud-Barnes material will be published later in a slightly modified form as a part of a very comprehensive report on the Ellenburger group of central Texas (see footnote p. 87). A special version of the ecological part of the general report is included here so that it may be brought to the attention of a large group that might not otherwise see it. The Committee does not intend, as a general rule, to include material in its reports that it knows will shortly appear elsewhere nor does itintend to include lengthy original articles and thus appear to compete with standard ecological journals that have better facilities for publication.

TREATISE ON MARINE ECOLOGY AND PALEOECOLOGY

In accordance with the plan mentioned in last year's report the Committee has prepared an outline for the proposed treatise on marine ecology. This outline is given below. In preparing it the Committee has benefitted from suggestions and information given by W. H. Bradley, M. I. Goldman, John B. Reeside, Jr., John W. Wells, and several others. The outline or table of contents is still regarded as a tentative one and it is hoped that it will be progressively improved by additional criticism as the job of writing the work gets underway.

TREATISE ON MARINE ECOLOGY AND PALEOECOLOGY

Introduction
- Ecology and paleoecology
- Aims of treatise
- Organization
- Acknowledgments

Ecology
- Physical and chemical features of environment
  - Depth, light, pressure, bottom, nearness to land, water movements, turbidity, temperature, salinity, oxygen, calcium carbonate equilibria, nutrient salts, pH
- Biological features
  - Food supply, organic communities, inter-relations of organisms, effects of organisms on structure of sediments
- Typical environments
  - Littoral zone
    - Eulittoral zone
      - Deltas, estuaries, fiords and other embayments, beaches, bars, dunes, lagoons, tidal swamps, tidal flats, rocky shores, reefs, reef lagoons
    - Sublittoral zone
  - Intermediate zone
    - Continental shelf and slope, banks, seamounts, basins, submarine canyons, straits
  - Abyssal zone
    - Ridges, flats, trenches
- Atypical environments and their deposits
  - Relict areas
  - Deposits containing dwarfed faunas and floras
  - Deposits resulting from outbursts of organisms
  - Deposits containing rafted materials
- Annotated bibliography of marine ecology

Paleoecology
- Paleontological record
- Evidence used in determining physical and chemical features of past environments
  - Depth, bottom, nearness to land, agitation, turbidity, temperature, salinity

Selected analyses from the geologic record
- Pre-Cambrian -- northwestern United States
- Cambrian -- Rocky Mountains
- Ordovician -- Llano Uplift, Texas
- Silurian -- Appalachian Region
- Devonian -- New York
- Mississippian -- Upper Mississippi Valley
- Pennsylvanian -- Eastern interior of United States
- Permian -- Trans-Pecos region, Texas
- Triassic -- Great Basin
- Jurassic -- Rocky Mountains
- Cretaceous -- Rocky Mountains
- Tertiary -- California
- Pleistocene -- Gulf Coast

Annotated bibliography of paleoecology

The treatise is divided into two parts, the first dealing with the various environments of organisms that may be recognized today, the second with the environments of the past in so far as they can be determined. Secondary headings, particularly in the ecological half of the outline, are strongly suggestive of topics that might be used in writing a treatise on sedimentation. This is understandable because the type of organisms living in a given place is determined by many of the same physical-chemical factors that determine the type of sediment deposited at that place. This relationship is a useful one, and a knowledge of present day relationships between organisms and sediments may serve as a guide in interpreting the environments of the past. The Committee, however, does not plan to duplicate the Treatise on Sedimentation or any part of it. Although sediments must of necessity be considered, the treatise here proposed will deal primarily with the ecology and paleoecology of the organisms buried in the sediments.

In the present initial stage only the broader topics have been included in the outline. Many of these will require subdivision when they are written. For example, the heading "Paleontological record" will include many items -- fossilization, condition of the skeleton or other hard parts, distribution of the fossils, criteria for recognizing mixed assemblages, etc.

The latter half of the treatise deals with paleoecology, and secondary headings under "Analysis of assemblages" are geologic and geographic. This part of the treatise is not designed as a detailed reference section for those who wish information about paleoecological conditions in any given period in any specific locality. In order to avoid the lengthy and deadly process of plowing methodically upward through all the strata of the geologic column, the world over the treatise will attempt an analysis of one or more assemblages from an outstanding region for each major time interval together with brief references to such other regions as may seem pertinent.

The outline in its present form does not recognize the importance of the annotated bibliographies. These are to be two of the most important sections of the volume. The references in each bibliography will be arranged on the basis of organic groups. With the help of these bibliographies, the paleontologist or biologist may obtain an overall picture of what is known of the ecology of a given organic group throughout its geologic history.

It is believed that the treatise will be found useful to biologists as well as to paleontologists. In addition to serving as a general reference work on questions involving ecology and paleoecology, it should offer a convenient starting point for detailed investigations. It is recognized that the job of preparing such a treatise will be a lengthy one requiring the active cooperation of a large number of individuals. The Committee expects to synthesize the work of this large number of contributors into one coherent treatise instead of publishing a series of separate and unrelated chapters by different authors. It is believed that the gain in continuity, uniformity in style, and reduction in duplication will more than justify the additional work involved. No individual authorship is contemplated. Instead, the treatise is visualized as a product of the Committee as a whole, and those who accept assignments will become members of the committee. It is hoped that the publication of a tentative outline at this time will lead interested paleontologists and biologists to volunteer to prepare chapters or other sections of the report.

CURRENT ACTIVITIES

EASTERN UNITED STATES

Dr. Joseph A. Cushman is studying the depth distribution of Foraminifera along a series of lines from shore to deeper water off the coasts of the Carolinas, Georgia and Florida. The study should yield data of value in determining the conditions under which Tertiary and Cretaceous strata were deposited in related areas. The materials were collected by the staff of the Woods Hole Oceanographic Institution and the study is supported by the Geological Society of America.

Miss Essie McCutcheon has completed a study of the seasonal distribution of the Ostracoda of Solomons Island, Maryland, under the direction of Dr. Willis Tressler of the University of Maryland. The study showed temperature to be the most important ecological factor; density and salinity were less effective controls; pH and transparency had no noticeable effects.

Miss Ruth Schmidt of the U. S. Geological Survey has undertaken a study of the Cretaceous and Eocene ostracodes of Maryland, Delaware and New Jersey. Miss Schmidt will spend part of the summer at the Chesapeake Bay Biological Laboratory on Solomons Island, Md., studying present-day forms and their environment.

MIDDLE UNITED STATES

Dr. Gordon Gunter of the University of Texas has completed a paper on the "Paleoecological Import of Certain Relationships of Marine Animals to Salinity." It will appear in an early issue of the Journal of Paleontology.

Mr. Joel W. Hedgpeth of the Game, Fish and Oyster Commission of Texas and Dr. Gordon Gunter are carrying on a study of the food organisms in ponds on the salt flats of the Aransas National Wildlife Refuge.

Prof. Willis G. Hewatt of Texas Christian University completed a hydrographic survey of Barataria Bay in Louisiana. This work was done during the

summer of 1945 while Professor Hewatt was visiting director of the Marine Laboratory of Louisiana State University at Grand Isle. In the fall of 1945 he was made visiting professor at the University of Puerto Rico at Mayaguez where he had an opportunity to study the marine fauna, particularly that of the coral reef.

The Institute of Marine Science of the University of Texas and the Texas Game, Fish and Oyster Commission plan to build marine laboratories at Port Aransas and Rockport respectively. Deeds to the properties have been obtained and architectural plans completed.

Dr. Fred B. Phleger, Jr. of Amherst College has submitted a brief statement outlining plans for ecologic studies in the Gulf of Mexico:

"During the late winter and early spring of 1947 personnel of the Woods Hole Oceanographic Institution will make an oceanographic reconnaissance of a part of the western Gulf of Mexico. This will be a complete oceanographic study but the principal effort will be focused on the sediments and on the ecology of the Foraminifera. The project will be financed in part by a grant from the Penrose Bequest of the Geological Society of America to F. B. Phleger, H. C. Stetson, and P. D. Trask. A large part of the cost of the study will also be furnished by the Woods Hole Oceanographic Institution.

"Four traverses will be made west of the Mississippi Delta from near shore to the center of the basin at approximately 2000 fathoms. The following materials will be collected on each traverse:

1. Undisturbed surface samples obtained from 10 to 12 inch cores. These will be 1 to 2 miles apart down to a depth of 500 fathoms, 5 miles apart between 500 and 1000 fathoms, and 10 miles apart between 1000 and 2000 fathoms.

2. Long cores (up to a maximum of 15 feet) will be taken 10 to 20 miles apart.

3. Quantitative plankton tows will be taken simultaneously at various depths. These will be approximately 25 miles apart.

4. Studies will be made on shipboard of plankton productivity. In connection with this, determinations of oxygen, phosphates, and nitrates of the water will be made.

5. Frequent temperature records will be made and complete hydrographic stations will be occupied at intervals of about 25 miles.

"Studies of foraminiferal ecology on this material will be as follows:

1. Population studies of living pelagic Foraminifera.

2. Population studies of living benthonic Foraminifera, if technical difficulties can be solved.

3. These living populations will be related to the accumulation of empty tests in the bottom sediments, and to distribution of temperature, chemical variations in the water, and general plankton distribution and productivity."

WESTERN UNITED STATES

John O. Burch of Los Angeles, California, continued his editorship of the monthly minutes of the Conchological Club of Southern California. The mimeographed minutes include much information on the occurrence and distribution of Pacific Coast marine mollusks.

Prof. Willis G. Hewatt has completed his ecological studies on Santa Cru Island, California. Marine invertebrates were collected at 6 shore stations and shallow water dredgings were made at 10 stations. A report describing results will be published in Ecological Monographs.

OUTSIDE THE UNITED STATES

Mr. R. W. Fairbridge and Dr. Curt Teichert have completed a second survey of an island reef in the Low Isles, Australia, that was used as headquarters by the British Great Barrier Reef Expedition in 1928. An aerial and ground survey gave excellent photo coverage which permitted them in 1945 to study in great detail the changes that have taken place on the island since 1928.

Prof. Robert W. Hiatt of the University of Hawaii is engaged in a series of studies on the ecology of certain types of coral reefs. He states:

"Extensive collections of marine fish, invertebrates, and plants are planned on four reef areas selected on the basis of the age and development of the reef. Types of reef areas to be studied are:

(1) a comparatively young, steep shore; lava substrata with coral attached directly to lava,

(2) shore with coral reef in early stage of development; lava completely covered, coral growing on older coral but still several fathoms below surface,

(3) shore with well developed coral reef which has grown approximately to surface and,

(4) a reef undergoing erosion; shoreward area composed of coral sand and mud; little or no living coral except at outer edge of reef bench."

The first of the above-mentioned types of reef was studied in 1945.

Professor Hiatt is one of a group of five zoologists who plan to make extensive collections on the island of Yap in the Caroline Group during the summer of 1946. Yap is looked upon as one of a series of strategic localities where large collections should be made in an attempt to learn more about the dispersal of marine species in the Pacific.

Operation Crossroads, Bikini Atoll. K. O. Emery, J. I. Tracy, Jr., H. S. Ladd and J. E. Hoffmeister of the U. S. Geological Survey made systematic studies at Bikini Atoll in the Marshall Islands in connection with the recent atomic bomb tests. K. O. Emery studied the lagoon and the sea bottom surrounding it. He states:

"The outer slopes around Bikini Atoll were found to rise from a depth of about 2500 fathoms in a long curved sweep which becomes steepest near the surface. Between 0 and 200 fathoms the average slope is 25°. On the windward side, the reef at the top of the slope is bordered by a narrow 15 fathom terrace, but on the leeward side by a steep, locally vertical, cliff extending to 35 fathoms. Contours of the outer slopes reveal that a flat-topped mass having nearly the area of Bikini lagoon but below 700 fathoms extends to the northwest. The lagoon itself is saucer-shaped and has a maximum depth of 34 fathoms. Around the lagoon and bordering the inner side of the reef and islands is a 12 fathom terrace. Coral patches (coral heads) rise abruptly from the lagoon floor and some of them reach to within a few fathoms of the surface. They are most abundant in the eastern half of the lagoon particularly near the edge of the lagoon terrace. The middle of the lagoon is floored chiefly by algal debris whereas the shallow edges are covered by algal and foraminiferal sand. Coral comprises a relatively small percentage of the bottom materials. The outer slopes consist of algal debris grading outward to fine sand and finally to Globigerina sand."

Tracy, Ladd and Hoffmeister studied the reefs and the island geology. They report:

"At twenty-six localities around the atoll detailed traverses were measured across the reef. They show the reef profile with its channels, pools, and caverns, the relative abundance of the important types of organisms and the occurrence of sediments, making it possible to recognize on the ground the zonation that is clearly indicated on air photographs. There are striking differences between windward and leeward reefs, between seaward and lagoonward reefs, between reefs bordering islands and those that make up the wide stretches between islands.

"By diving and swimming with face masks it was possible to examine deep pools in the blow-hole zone and the room-and-pillar structure that is locally developed beneath this part of the reef. The surge channels of the reef edge and the seaward slopes of the reefs themselves were studied by the same means. Parts of the lagoon floor and the coral mounds that rise from it were examined by diving.

"Calcareous algae are widespread. They form a distinct Lithothamnion Ridge along the seaward edge of the windward reefs and Halimeda covers much of the lagoon floor. Corals and their near relatives are abundant but their growth is not as prolific as that which characterizes the reefs in parts of the southwest Pacific. In spite of intensive collecting, several common coral genera were not found on Bikini. The species list, however, is large, a total of 115 having been identified to date by J. W. Wells, who is studying the collections."

Marston Sargent of the Scripps Institution of Oceanography and Thomas Austin of the Hydrographic Office report as follows on their ecological investigations:

"During the recent Navy Expedition to the Northern Marshalls, an opportunity was afforded for a partial study of the ecological relationships of the

marine, lagoon and reef environments of three atolls, namely, Bikini, Rongelap and Eniwetok. These studies included determinations of the total organic production, the concentration of the biologically affected factors, oxygen and phosphate (PO_4), and of the temperature, transparency and salinity of the oceanic and lagoon waters and the waters crossing the reefs. Also, diurnal studies were made in several tide pools and solution basins which, at low tide, were isolated from the lagoonal and oceanic circulation. The bacteriological and Biological Oxygen Demand (B.O.D.) investigations of Bikini and Rongelap Lagoons, which will be partially discussed in this report, were made by Dr. Donald Johnstone of the Microbiology Department, Rutgers University and the Woods Hole Oceanographic Institution.

"Before a complete report of the studies is submitted, data concerning such factors as the abundance of zooplankton and phytoplankton in the lagoons and in the oceanic waters surrounding the atolls, the distribution of the algae on the lagoon bottom, the zonation of the corals and the algae across the reef and the meteorological conditions existing during the period of the investigation are necessary. However, some general conclusions can be drawn from the data at hand and will be discussed in this report.

"First, the organic production in the lagoon and on the reefs was determined from the dissolved oxygen and phosphate content of the waters and measurements of the change in content of these biologically active substances. Measurements made in Rongelap Lagoon showed an average production of 0.007 ml of oxygen per liter of water per twenty-four hours. Corrected for the volume of the water in the lagoon, this figure gives 150 tons of carbon or 0.19 grams of carbon per square meter per day. Similar measurements in Eniwetok and Bikini Lagoons indicate a somewhat higher total production of organic matter. However, as all experimental values are close to the minimum measurable value, it is not certain that these differences are significant. Compared with measured values in other waters, both are low. As no seasonal variation in the abundance of phytoplankton was noted during the five months in the Northern Marshalls, it is believed that the above-mentioned figures for the average daily production can be used for the calculation of the annual total production. For Rongelap Lagoon this would amount to 55×10^3 tons of organic carbon per year.

"In Rongelap Atoll, measurements indicated that the average organic productivity of the reef inside the surf zone was about 0.9 grams of carbon per square meter per day. Although the area of the reef is less than four percent of the area of the lagoon (28 km^2 and 810km^2 respectively) the total annual production of the reef is over sixteen percent of that of the lagoon (9.2×10^3 and 55×10^3 tons of organic carbon per year respectively).

"The figures for the organic production on the reef include that produced by the zooanthelle of the corals, the algae comprising the very extensive mat covering the reefs which consists of such forms as Centroceras, Jania and many fragile calcareous bushy algae and the small quantity of phytoplankton in the waters flowing over the reefs. An estimation of the organic content of the reef water can be made from the B.O.D. One sample, taken on the reef at a point well inside the surf zone, gave an oxygen consumption after six days' incubation of 0.25 ml per liter while the second sample, taken a short distance

off the lagoon side of the reef, gave 0.73 ml per liter. This latter sample shows considerable influence of the lagoon waters.

"The values for the phosphate content of the oceanic waters were consistently higher than those for the lagoon, indicating the greater productivity of the lagoon. Again referring to the result of the B.O.D.'s, we see that a station five miles seaward, to the east, from Rongelap Reef gave an oxygen consumption after six days incubation of 0.92 ml per liter. This is to be compared with the result of the lagoon sample, 0.73 ml per liter. Immediately seaward from the reef well within the surf zone, the oxygen consumption after a similar period of incubation was 2.04 ml per liter. This may be explained by the action of the surf flushing the organic material from the seaward face of the reef and carrying it a few hundred yards out to sea. Current studies, made by the use of fluorescein dye, indicated that following the breaking of each wave, a large percentage of the water from the Lithothamnion ridge and the face of the reef was carried seaward to be brought back in the next wave. Also, the waters immediately off the windward side of the reef are enriched by upwelling, a factor supported by the phosphate, salinity and temperature measurements.

"Current surveys in both Bikini and Rongelap Lagoons demonstrate that the circulation of the lagoon is dominately wind driven. The current sets down wind on the surface and roughly against it on the bottom. In the western end of the lagoon the surface water sinks and returns to the surface at the eastern end as a region of upwelling.

"The oxygen content of the surface, wind driven waters was usually lower than that of the bottom return current while the reverse was true for the phosphate values. It seems reasonable that along the bottom, as on the reefs, these low phosphate, high oxygen values are due to the utilization of the nutrient salt and an increase of oxygen resulting from the photosynthetic activity of the sessile algae. Analyses of the material from snapper and dredge samples indicated the presence of luxuriant growth of Halimeda, Caulerpa and other algae. However, this condition does not exist for a short distance lagoonward from the windward reef, the region of upwelling. The bottom water over this area is relatively low in oxygen and high in phosphate. The bottom is characterized by the absence of sessile algae and a relatively high percentage of organic material in the bottom sediments.

"The B.O.D. for a sample near the lagoon bottom along the Eastern reef of Bikini Atoll was approximately 1.70 ml per liter after six days incubation. Near the center of the lagoon, the B.O.D. for a sample taken near the bottom was less than 1 ml per liter after a similar period of incubation. It would seem that in the center of the lagoon the photosynthetic activity of the algae supplies enough oxygen to oxidize the small quantity of organic material that drifts down from the upper waters. However, along the reef as a result of the sedimentation of the organic material flushed from the reef and the absence of sessile algae, the organic material has an opportunity to accumulate in the bottom sediments. Bacteria counts for the sample taken near the reef were about 330 per cubic centimeter, decreasing to an average of 30 per cubic centimeter for the mid-lagoon waters.

"During the periods of low tide, there are numerous small tide pools, located on the reef flat and solution basins in the conglomerate which are isolated from the general lagoonal and oceanic circulation. The bottom of the tide pools are covered by a consolidated putty-like stratum of fine sand, Schizothrix and Foraminifera. Numerous patches of coral, and several species of Sea Cucumber and small fish are often found in the pools.

"The diurnal ranges observed in the tide pools averaged 3.5 ml. per liter for oxygen, 0.45 microgram atoms per liter for phosphate and 15°F for temperature. Following the numerous tropical showers, very high temperatures (110° and intense stratification were developed in the solution basins. An understanding of the ecological significance of the variations encountered during a twenty-four hour series is dependent on many factors, such as depth of the pool, ratio of the depth to the area, total radiation, wind velocity, and the chemical and physical composition of the water which floods the pool twice daily. Considerable study and integration of these factors must be made befo the complete analyses can be reported."

Mr. A. W. B. Powell of the Auckland Institute and Museum is assembling available data on depth ranges and substrata of a large number of New Zealand mollusks. Mr. Powell and C. A. Fleming of the New Zealand Geological Survey are using these data in interpreting the Castlecliffian Upper Pliocene faunul

Dr. J. H. F. Umbgrove has completed a comprehensive paper on the coral reefs of the East Indies. It will be published at an early date by the Geological Society of America.

The United States Geological Survey has initiated a long-term program of geological work including areal mapping in the islands of the Pacific. The first unit in this program is the island of Okinawa in the Ryukyu Group. An important part of this study will be detailed mapping of several facies in the Plio-Pleistocene Ryukyu limestone which is widely exposed in the southern half of the island.

RECENTLY PUBLISHED PAPERS

Most of the papers listed below appeared during the year ending May 1, 1946.

GENERAL

Alling, Harold L., Use of microlithologies as illustrated by some New York sedimentary rocks, Bull. Geol. Soc. Amer., vol. 56, no. 7, pp. 737-756, 1945.

Bryan, W. H., Relationship of Australian continent to the Pacific Ocean - no and in the past, Royal Society of New South Wales, Jour. and Proc., vol. 78, pp. 42-62, 1945.

Clark, Bruce L. and Durham, J. Wyatt, Eocene faunas from the Department of Bolivar, Columbia, Geol. Soc. Amer., Mem. 16, pp. 1-126, 1946.

Clifton, R. L., Permian Word formation: its faunal and stratigraphic correlatives, Texas, Bull. Amer. Assoc. Petrol. Geol., vol. 29, pp. 1766-1776, 1945.

Conway, Edward J., Mean losses of Na, Ca, etc., in one weathering cycle and potassium removal from the ocean, Amer. Jour. Sci., vol. 243, pp. 583-605, 1945.

Cooper, Byron N. and Cooper, G. Arthur, Lower Middle Ordovician stratigraphy of the Shenandoah Valley, Virginia, Bull. Geol. Soc. Amer., vol. 57, pp. 35-114, 1945.

Daly, Reginald A., Comments on "Geology of Lau, Fiji," Amer. Jour. Sci., vol. 243, no. 10, pp. 565-571, 1945.

Edmondson, C. H., Reef and shore fauna of Hawaii, Bernice P. Bishop Museum, Spl. Pub. 22, pp. 1-381, 1946 (Revised Ed.).

Fuller, John L., Season of attachment and growth of sedentary marine organisms at Lamoine, Maine, Ecology, vol. 27, pp. 150-158, 1946.

Gislen, Torsten, Physiographical and ecological investigations concerning the littoral of the North Pacific, Sec. 1, A comparison between the life-conditions in the littoral of central Japan and California, Kunge. Fisiogr. Sallsk. Handl. N.F. Bd. 54, Nr. 5, pp. 1-64, Lund, Sweden, 1943.
Sec. 2-4, Regional conditions of the Pacific Coast of America and their significance for the development of marine life, Bd. 55, Nr. 8, pp. 1-91, 1944.

Graham, Herbert W. and Helen Gay, Season of attachment and growth of sedentary marine organisms at Oakland, California, Ecology, vol. 26, pp. 375-386, 1945.

Gromov, V., Twenty-five years of the study of the Quaternary in the U.S.S.R., Amer. Jour. Sci., vol. 243, pp. 492-516, 1945 (Transl. by M. K. Elias).

Henderson, G. T. D. and Marshall, N. B., Continuous plankton records: The zooplankton (other than copepoda and young fish in the southern North Sea, 1932-37), Hull Bull. Marine Ecol., vol. 1, pp. 255-275, 1944.

Hertlein, Leo George and Grant, U. S. IV, The geology and paleontology of the marine Pliocene of San Diego, California, Geol. Mem. San Diego Soc. Nat. Hist., vol. 2, pp. 1-72, 1944.

Ives, Ronald L., Bottle springs, Jour. Geology, vol. 54, no. 2, pp. 123-125, 1946.

Freshwater springs in the Great Salt Lake are locally called "bottle springs" from ranchers' ability to get fresh water from them by opening an empty bottle immediately over the spring. Freshwater diatoms and other algae live in a roughly spherical zone above the spring, completely surrounded by salt water.

Kuenen, Ph. H., Bottom samples, Section I, Collecting of the samples and some general aspects, The Snellius-Expedition, vol. 5, Geological Results, part 3, pp. 1-46, 2 pls., 6 text-figs., 1943. (See also Neeb, G. A.)

McKay, Donald C. G., Notes on the aggregating marine invertebrates in Hawaii, Ecology, vol. 26, pp. 205-207, 1945.

McKee, Edwin D., Cambrian history of the Grand Canyon region, Pt. 1: Stratigraphy and ecology of the Grand Canyon Cambrian, Carnegie Inst. of Washington, Pub. 563, pp. 1-168, 1945.

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Cushman, Joseph A. and Todd, Ruth, Miocene Foraminifera from Buff Bay, Jamaica, Cushman Lab. Foram. Research, Spl. Pub. 15, pp. 1-73, 1945.

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Habitat, extrusion of planulae, reactions to food, and types of nematocysts are considered. The food is entirely of animal origin.

Caster, Kenneth E., A new jelly fish (Kirklandia texana Caster) from the lower Cretaceous of Texas, Palaeontographica Americana, vol. 3, no. 18, pp. 1-52, 1945.

Durham, J. Wyatt, Corals [in Clark, B. L., and Durham, J. W., Eocene faunas from the Department of Bolivar, Columbia,] Geol. Soc. Amer. Mem. 16, Part II, pp. 77-82, pls. 25-27, 1 text-fig., Feb. 28, 1946.

Nine species are described -- seven new, one not named, one previously named. There is a paragraph on ecology.

Hudson, Robert George Spencer, The variation in an assemblage of the Caninia cornucopiae plexus from the middle Visean, Quart. Jour. Geol. Soc. London, vol. 100, pp. 193-207, 1945.

Rayner, Dorothy H., A D_2 coral bed near Settle, Trans. Leeds Geol. Assoc., vol. 6, pp. 14-25, 1946.

A discussion of the ecology of the most luxuriant of the coral-rich patches that are included in the Lower Carboniferous Visean limestone. Twelve species of corals are recognized, the overwhelming majority of specimens being compound forms. The author found no indication of long emergence above tide level; few, if any, of the corallar are overturned. The density of coral growth is compared to the thinly populated areas of a lagoon but no evidence was found to indicate that the deposit was ever a part of a major reef structure. The occurrence is compared to a "patch reef" such as are known from the East Indies at depths of 10-20 meters. The author does not believe however, that the deposit should be called a "reef" but rather a growth of "reef corals" in fairly quiet, fairly shallow water, a concentration that may have owed its inception to a small sandy patch on the sea floor.

Umbgrove, J. H. F., Madreporaria from the Togian reefs (Gulf of Tomini, North Celebes), Zool. Meded., vol. 22, pp. 265-310, pls. 21-35, 3 text-figs., 1940.

The general conditions under which the corals occur are described and about 91 forms are listed, most of them described, and many well illustrated.

Umbgrove, J. H. F., Corals from asphalt deposits of the Island Buton (East Indies), Leid. Geol. Meded., vol. 13, pp. 29-38, pls. 12, 13, 1 text-fig., 1942.

Ten species of corals, one undetermined, are noted, nine of them described and figured, and the mould of a cocoanut is also described and figured. It is thought that the corals were brought to the place when collected by a mud volcano.

Umbgrove, J. H. F., Evolution of reef corals in East Indies since Miocene time, Amer. Assoc. Petrol. Geol., Bull., vol. 30, no. 1, pp. 23-31, 2 text-figs., 1946.

The percentages of living species of corals are discussed for the different horizons of the Tertiary, 0 for the Eocene, 0 to very few for the Oligocene, 0 (?) to 50% for Miocene horizons e to g, 50-70% for the Pliocene, 70-100% for the Pleistocene. An estimate of the age in millions of years is made for each of the principal successive horizons. Two periods of accelerated speciation are noted, later Miocene and Pleistocene. An attempt is made to correlate the recorded phenomena with geological events.

Wells, John W., West Indian Eocene and Miocene corals, Geol. Soc. Amer. Mem. 9, pp. iv+25, 3 pls, 1945.

This paper is divided into two parts as follows: Corals from the Eocene Upper Scotland formation of Barbados, from which 26 species are recorded; 2 are identified with, one compared with previously described species; 16 species, one variety, and two genera are described as new; 5 even species are undetermined. The ecology of the fauna is discussed. The second part is entitled "Two corals from the Miocene of Martinique," one of them is new.

Wells, John W., Some Jurassic and Cretaceous corals from northern Mexico, Jour. Paleon., vol. 20, pp. 1-7, pls. 1-2, January 1946.

There are notes on the ecology of the faunas.

Yabe, Hisakatsu, and Eguchi, Motoki, Fossil and Recent Flabellum from Japan, Tohuku Imperial Univ. Sci. Repts., 2nd ser. (Geol.) vol. 22, no. 2, pp. 89-103, pls. 5-8, 1942.

Eight species and five varieties are described and figured. Ecologic data are available for most of the Recent specimens.

Yabe, Hisakatsu, and Eguchi, Motoki, Fossil and Recent simple corals from Japan, Tohoku Imperial Univ. Sci. Repts., 2nd. ser. (Geol.) vol. 22, no. 2, pp. 107-178, pls. 9-12, 1942.

For the Recent corals full ecologic data are given.

VERMES

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Discusses burrows and relations to feeding.

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Loosanoff, Victor L., Effects of sea water of reduced salinities upon starfish, A. forbesi, of Long Island Sound, Trans. Connecticut Acad. Arts and Sci., vol. 36, pp. 813-836, 1945.

All starfish exposed to water of 16 p.p.t. died; no acclimatization; threshold of tolerance 16-18 p.p.t.

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BRACHIOPODA

Stainbrook, Merrill A., Brachiopoda of the Independence shale of Iowa, Geol. Soc. Amer., Mem. 14, pp. 1-74, 1945.

MOLLUSKS

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Frizzel, Don L., A study of two arciel Pelecypod species from western South America, Jour. Paleon., vol. 20, pp. 38-51, 1946.

Gardner, Julia, Mollusca of the Tertiary formations of northeastern Mexico, Geol. Soc. Amer., Mem. 11, pp. 1-332, 1945.

Miller, A. K. and Cullison, James S., Early Ordovician Cephalopods with subterminal apertures, Jour. Paleon., vol. 20, pp. 158-162, 1946.

Roger, Jean, Le Genre Chlamys dans les Formations Neogenes de l'Europe, Soc. Geol. de France, Mem., new ser., vol. 17, fasc., 2-4, Mem. No. 40, pp. 1-294, pls. 1-28, 113 text-figs., graphs and charts: quarto, Paris, 1939.

The greater part of the monograph is concerned with a detailed systematic treatment of the genus. The types of variation in the species are considered: (1) Ontogenetic variations; (2) fluctuant variation, translated into the binomial curve of Quetelet; (3) variation due to external stimuli; species of large size are found in the warm seas where calcium carbonate abounds; smooth species of small size and pellucid shells are confined to deep or cold waters; (4) phylogenetic variations; the explosive development of certain groups in the upper Miocene may indicate or be associated with a transgressing sea and consequent unstable conditions. Identical characters appear in distinct groups. (a) The nodose ribs in the Chlamys Tournali race

are similar to those in C. nodosa. This fact has been attributed to conditions in the environment which produce the same reaction in different groups. (b) The bifurcation of the ribs in the right valve and the intercalation of ribs in the left valve is evident in the races typified by Chlamys scabriuscula, C. flexuosa, C. scissa, C. clavata, and C. multistriata. These attributes are certainly a function of the mechanism of shell secretion and possibly are concerned with mutations. (c) The disappearance of the external ribbing in Chlamys typified by C. flexuosa, C. hyalina, and C. excisa, in Pectens of the P. benedictus race, and in Flabellipecten typified by F. burdigalensis probably involve the mode of secretion of the shell and the environmental conditions. (d) The secondary macroscopic ornamentation gives rise to some remarkable analogues: That of Chlamys scabrella to that of C. scabriuscula and C. pes-felis; and the spinose ornamentation of C. Northamptoni to that of C. opercularis s.l.

This ornamentation is the result of the combination of the concentric and the radial sculpture. The rapidity of the ontogenetic evolution of one or the other lends a considerable range of variation to the adult shell. (e) Microscopic ornamentation of the Camptonectes type is found in groups as diverse as those of Chlamys pes-felis, C. scissa, C. varia, and C. opercularis. It is interpreted as the persistence of a juvenile sculpture common to most Chlamys. The terms "iteratif" or "converging characters" have been used for similar features appearing in distinct groups. The more significant include the contour of the shell, the profile, the cut of the ears, the byssal sinus, the existence of flat ribs or rounded grooves on the internal surfaces and the strength of the cardinal armature.

Utilizing the morphological characters and the distribution in space and in time, it has been possible to define the species, to assemble them in phylogenetic groups, and to assemble the groups under two categories:
1. Chlamys s.s. characterized by a high outline; unequal ears, the anterior larger than the posterior; and rippled ribbing on the inner surface.
2. Aequipecten Fischer characterized by a more or less rounded shell, subequal ears and sharply defined internal ribs. Chlamys s. s. has been reported from the Carboniferous and is probably older than Aequipecten. Pecten, Flabellipecten, and Amussium are also considered but less exhaustively than Chlamys.

The Pectens are widely distributed in the Recent seas, which are subdivided into the Arctic, Boreal, Celtic, Lusitanian, and Aralo-Caspian Provinces. Except for Chlamys islandica, the Arctic species are of small size, and the shells are thin and commonly transparent. The shells are small and thin in the Boreal Province also, and, as in the Arctic, Pecten, Flabellipectin, and Amussium are absent. Chlamys is more common, and Pecten maximus is present in the Celtic zone. In the Lusitanian Province, including the Mediterranean, both individuals and species are more numerous. In the Mediterranean, Pecten Jacobeus replaces P. maximus of the Celtic Province. The widely distributed species, such as Chlamys multistriata, C. opercularis, and C. varia increase in abundance from north to south. The fauna of the Lusitanian Province differs widely from that of the Indo-Pacific, for example, in the varieties of Pecten and Amussium which are common in the Indo-Pacific.

The Pectens are, for the most part, bottom dwellers. Some of them rest on the bottom, some are attached by a byssus, and some are free swimmers. The adult swimmers propel themselves by clapping the valves, but the young make use of the foot as a swimming organ and, as pelagic or planktonic forms, may range widely along the shore. The number of littoral species is relatively small. Several species of Chlamys, Pecten maximus, and P. Jacobeus are characteristic of the Laminarian-facies of the deep littoral zone at a depth of 3 to 30 meters. The pectinid fauna is richer in the Nullipore and Corraline zones from 30 to 72 meters and in the even deeper waters from 72 meters to the edge of the continental shelf. In the abyssal zone from 500 meters down the shells are uniformly of small size. The distribution of the Pectens is also influenced by the character of the bottom. Some of the Chlamys, notably C. varia and C. multistriata, thrive on the rock and gravel bottoms. The large Pectens, such as P. maximus and P. Jacobeus, frequent the sandy bottoms and also the seaweed. Most of the muddy bottom species have notably thin shells.

The character and distribution of the Neogene pectenid faunas are checked against the Recent. The lower Miocene Mediterranean fauna has a tropical aspect. It is rich both in species and in individuals. In richness it is comparable to the Indo-Pacific fauna, and, like it, includes Amussium of large size and large, thick-shelled Chlamys. As in the Recent seas, the northern lower Miocene faunas are much less rich and varied. The eastern and western Mediterranean faunas show marked differences. The southern outcrops of the oriental Mediterranean faunas include several species common to the Egyptian and Cyrenian faunas. Probably communications with the Indian faunas were intermittently open. The Portuguese fauna includes several species common to those of the Mediterranean, but the Aquitanian fauna is so distinct that interrupted communications may be inferred. The origin of the lower Miocene European faunas is not entirely clear. The shallow seas connecting the Indo-Pacific waters with those of the Mediterranean doubtless encouraged migrations from the East. However, the similarity of some of the large species of Chlamys to Lyropecten of the West Atlantic has suggested the possibility of the difficult passage of the Atlantic and a favorable consideration of the Atlantis hypothesis is advanced. Species of the Chlamys opercularis group were probably migrants from the North. A few species, including C. Northamptoni, developed in situ from Oligocene ancestors.

The general transgression signalizing the middle Miocene is reflected in the bourgeoning of the Pectenid faunas, especially along the Italian and south Mediterranean shores. Much of the richness of the faunas in the western Mediterranean may be due to the diversity of the environment, for the sediments include calcareous sandstone, sandstone, white chalk, greensand, and clay. The eastern Mediterranean, including the Vienna basin, is not so rich a province as the western Mediterranean, but the number of new elements in the fauna is striking. Amussium, for example, increases in abundance with the deposition of finer sediments. The similarity of the Mediterranean faunas to those of the Vienna basin make it probable that the lines of communication between the basins were open. Of the three basins open to the Atlantic, the Loire and the Aquitanian closely resemble each other, and that of Portugal has much in common with the Mediterranean faunas. On the whole, the fauna of the middle Miocene is more uniform than that of the lower, and intermigration was probably facilitated by the transgressing sea. The waters were

probably a little cooler than in the lower Miocene but still subtropical, and the shores were shifting with some deeps and islands and archipelagos.

In the upper Miocene the sea withdrew slightly, and the basins were to a certain degree isolated. That in the neighborhood of Venice was cut off from the peri-Alpine trough and partially isolated from the eastern Mediterranean basin; in it a varied sedimentation was accomplished with sands rich in Pectenids dominant. In the Vienna basin most of the species are relicts of the middle Miocene fauna but less, or in the case of some species, more abundant. About a dozen species of Pectenids are new, some of them endemic, some derived from species in other areas of the Mediterranean. In the Galician basin also the Pectenid fauna is renewed by evolution within the framework of the basin. Pecten Jacobeus, a Recent Mediterranean species made its appearance in the Redonian of Anjou. In the northern fauna, known from Belgium and from Holstein, the Pectenid fauna is rather meager and of negative character. Some of the species are similar to those in the Polish fauna.

The relations of land and water at the opening of the Pliocene were similar to the present. The peri-Alpine trough no longer existed, and the eastern and western Mediterranean formed a single body of water. The trough at the mouth of the Rhone extended to Lyon. The regression at the close of the Miocene was followed by a transgressing Pliocene sea, and the consequent enrichment of the fauna. The four Pectenid genera were represented, but Chlamys was the most abundant. The species of large size so conspicuous in the Miocene faunas were few or absent. Roger considers their decline as an indication of lowered temperature, but the prevalence of large species in the Maryland Miocene does not bear out that inference. The Straits of Gibraltar were open during the lower Pliocene, and intermigration between the Atlantic and Mediterranean faunas was free. The lower stratigraphic unit, the Plaisancien, was finer, more marly, and of deeper water origin than the more sandy and later Astian. For that reason thin-shelled species and Amussium are best represented during the Plaisancien. The Pliocene Crag of England is much richer than the Miocene. The distribution of the Pectens in that area was similar to that of the present day.

The only important later Pliocene deposits are those of Calabria. The fauna is rich but several species characteristic of the older Pliocene have disappeared. A few have come in from the North. The ensemble of the fauna indicates a cooling of the sea or at least currents of cold water. According to Prof. Stefanini the Calabrian marks the end of the glacial period. Apparently also the salinity and density of the water were lowered by the abundance of the rainfall. The northern facies is still further emphasized during the Pleistocene, and the faunas more closely approach the Recent.

The illustrations, especially the paleogeographic maps, are excellent.

A bibliography of 259 citations concludes the monograph.

(Julia Gardner.)

Russell, Henry D., Ecologic notes concerning Elysia chlorotica Gould and Stiliger fuscata Gould, Nautilus, vol. 59, pp. 95-97, 1946.

Test, Avery Ransome, Ecology of California Acmaea, Ecology, vol. 26, pp. 395-405, 1945.

Test, Frederick H., Substrate and movements of the marine gastropod Acmaea asini, Amer. Midland Naturalist, vol. 33, no. 3, pp. 791-793, May 1945.

Vokes, H. E., Protodonax, a new Cretaceous molluscan genus, Jour. Paleon., vol. 19, pp. 295-308, 1945.

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Pearse, A. S., Ecology of Upogebia affinis (Say), Ecology, vol. 26, pp. 303-305, 1945.

Ecology of the common Atlantic mud shrimps.

Pohl, Marian Evelyn, Ecological observations on Callianassa major Say at Beaufort, North Carolina, Ecology, vol. 27, pp. 71-80, 1946.

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David, Lore Rose, Some typical upper Eogene fish scales from California, Carnegie Inst. Wash. Pub. 551, pp. 45-79, 1946.

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Romer, Alfred Sherwood, The late carboniferous vertebrate fauna of Kounova (Bohemia) compared with that of the Texas Red beds, Amer. Jour. Sci., vol. 243, pp. 417-442, 1945.

PROBLEMATICAL FOSSILS

Ellison, Samuel P., Jr., Conodonts or Paleozoic guide fossils, Bull. Amer. Assoc. Petroleum Geol., vol. 30, pp. 93-110, 1946.

ADDITIONAL JAPANESE REPORTS

by

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The papers abstracted in the following pages are those which were not accessible or were overlooked at the time the 1945 Report of the Committee was made up. Nearly all of them were published before 1942 and those which came out later may have been written before the opening of the war. Copies of a few of the Bulletins of the Tropical Industry Institute at the seaside laboratory at Palau have been brought back by overseas workers. The most important group of papers recently made available is that assembled in the two volumes of the Jubilee Publication in the Commemoration of the Sixtieth Birthday of Professor Yabe of the Tohoku Imperial University of Sendai, Japan. A larger percentage of the later papers seem to have been published in Japanese, some with short English abstracts but some with even the dates in the Japanese calendar.

The Japanese concept of a formation seems to differ from that of the American geologist, and the name seems to imply little more than a locality at which certain beds are well exposed. The correlation of these numerous outcrops is not well established especially within Japan proper. In the Marianas, Palau and other islands built up largely of limestone, the conditions affecting deposition and the included fauna may have been less local for the correlations seem more sure.

Yabe, Hisakatsu and Hanzawa, Shoshiro. A Geological Problem Concerning the Raised Coral-Reefs of the Riukiu Islands and Taiwan: A consideration based on the fossil Foraminifera faunas contained in the Raised Coral-Reef formation and the youngest deposits underlying it. Tohoku Imperial Univ., Sendai, Japan, Sci. Repts., 2d ser., (Geology), Vol. 7, No. 2, pp. 29 (1)-56 (28); pls. 5 (1)-10 (6), 1925.

Raised coral reefs are extensively developed in the Riukiu Islands. Most of the reefs are horizontal and are built up on inclined beds of Tertiary or Paleozoic sediments or on igneous rocks. They are more elevated and more indurated than the Recent reefs, and the original color has been lost. Although the reefs were believed by Tokunaga to be contemporaneous, the elevation ranges from 10'-20' on Minna-jima to 684' on Kikaiga-shima.

Similar coral reefs are developed on southern Taiwan. The limestone from Takao, Taiwan, is white with a yellowish tinge and somewhat porous. It is essentially an aggregate of the tests of Foraminifera, echinoid spines, Bryozoa, and calcareous algae. The rock was earlier referred with some question to the Tertiary, but, like the limestones of the Riukiu Islands, it is probably of Pleistocene age.

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The Island of Miyako is roughly triangular with its base to the south and an elongated peninsula to the north. The reef limestone, built up on the inclined Tertiary sandstone and shale beds, consists mainly of coral and coral fragments with some shells such as Arca, Tapes, Fusus, Tridacna, and Natica. The thickness is estimated at 100 feet.

On Okinawa-jima, reef limestones are developed chiefly in the southern part of the island on an extensive area of Tertiary rocks and on a more restricted Paleozoic surface. A species of calcareous algae is the dominant organism on Okinawa. The thickness of the reefs is small in comparison with their extent. The elevation above sea level ranges from 121' to 598' but a boring entered the underlying Pliocene sediments at 30 feet. Probably Shimajiri was at one time entirely covered by reefs, and the present discontinuous patches are remnants of a former continuous mantle. The eastern half of the district of Shimajiri forms a plateau several hundred feet high. Toward the east is a steep escarpment generally with a flat alluvial plain at the base; toward the west the slope is gentle, commonly terraced, and cliffed along the shore. The raised reefs are found not only in Shimajiri but also in Kunchan, on the east coast near Kin, and in the northern part of the Peninsula of Motobu.

On Okinoerabu-jima small hills of Paleozoic rocks trending northeast to southwest are encircled by reefs raised to about 200 feet above sea level. A few terraces near the coast break in cliffs 20 to 30 feet high.

Toku-no-shima also is made up of Paleozoic and igneous rocks encircled on the western, southern, and southeastern parts of the island by an extensive plateau of reef limestone.

Two distinct foraminiferal faunas are included in the limestone samples from these various localities, the one characterized by Operculina bartschi punctata, the other by Cycloclypeus and Siderolites. An Operculina so large as O. bartschi has not been recorded north of the Philippines. The species of Cycloclypeus and Siderolites are characteristic of Philippine waters rather than of those so far north as the Riukius. The foraminiferal fauna as a whole is similar in a general way to the Recent fauna recorded by Cushman from the two Albatross Stations in Vincennes or Colnett Strait, one at 60 fathoms with a bottom temperature of 26.2° C.; the other from 248 fathoms with a bottom temperature of 9.3° C. Many of the tropical Foraminifera have not been recorded north of these stations. Operculina bartschi punctata is common to the limestones from Okinawa-jima, Okinoerabu-jima, and Tokuno-shima and Cycloclypeus and Siderolites to the limestones from Taiwan, Miyako-jima, and Okinoerabu-jima. It is probable that not only are the limestones of the different groups synchronous with each other, but the two groups are probably contemporaneous. Operculina bartschi, which dominates the fauna of the first group, and Cycloclypeus gumbelianus, which dominates the fauna of the second, have a similar past and present geographic distribution.

The youngest rocks underlying the reef limestones were determined by Tokunaga to be of Pliocene age. The elevation of the reef limestones may have been accomplished in pre-Pleistocene, Pleistocene, or post-Pleistocene times.

Daly has stressed the evidence that reef building corals cannot thrive i the Hawaiian Islands between Lat. 18° 55' and 23° N. The surface temperature of the shore water in that area does not greatly exceed 20° during the winter months. If the entire ocean surface were chilled during the Pleistocene the waters of the Riukiu Islands and Taiwan which lie between 22° and 31° would not be favorable to coral growth. The fauna of the older reefs differs, however, from the Recent faunas of the adjacent seas in its more tropical aspect

The indented shore line of the Riukius encircled by a relatively broad wave-cut bench, commonly one kilometer in breadth and covered by fringing reefs, indicates a fairly long period of time since the uplift of the reef limestone. On Miyako-jima the reef limestone is tilted from east to west, but the island is surrounded by a submarine shelf 12 kilometers broad, indicating that the limestones were tilted before the development of the shelf.

The following sequence may be traced:

1. Warping of Tertiary and pre-Tertiary shales, sandstones, and igneous rocks.
2. Marine abrasion and reef-building on the abraded surface.
3. Upheaval accompanied by tilting of reef limestones.
4. Marine erosion and formation of broad shelf by wave abrasion and deposition.
5. Further elevation of strand line; formation of narrow wave-cut coastal bench.

The geologic data and paleontologic record indicate that the reef limestone cannot be so young as the post-Pleistocene. Yokoyama has recorded an opinion that the Pleistocene climate of Japan was not cold but warm. Daly, however, assumed a universal cooling, which rules out the Pleistocene age of the limestone and would indicate a probable pre-Pleistocene age.

The present data is not sufficient to determine the stratigraphic and morphologic implications of the violent late Cenozoic crustal disturbances along this belt of the Pacific.

Tamura, T., and Hada, Y. Growth Rate of Reef Building Corals Inhabiting the South Sea Islands. Science Reports, Tohoku Imperial Univ., (4) Biology, Vol. 6, No. 3, pp. 433-455, 1932.

The growth rate of corals at Yap and Palau Islands is quite similar to that of corals in Hawaii.

Amemiya, Ikusaku and Ohsima, Yasuo. Note on the Habitat of Rock-boring Mollusca on the Coast of Central Japan. Imperial Academy, Tokyo, Proc., Vol. 9, pp. 120-123, 2 tables, 1 diagram, March, 1933.

Deep tubular perforations made by certain genera of Mollusca in certain kinds of rocks may endure for long periods of time especially when lifted above sea level. Their tubes exposed on the sea cliffs may be important evidence in measuring the extent of earthquake action.

Seven species of rock borers have been recognized on the Pacific coast of Central Japan: Barnea fragilis Sowerby, Zirfaea crispata Linné, Pholadidea penita Conrad, Parapholas quadrizonata Spengler, Jouannetia globosa Quoy et Gaimard, Jouannetia japonica Yokoyama and Lithophaga curta Lischke. Rocks of homogeneous consistency, even though hard and chemically stable are attacked by the borers. Conglomerates, however, even though brittle are not invaded. Lithophaga, which in the Gulf of Naples penetrated only limestones, attacked the tuffaceous rocks of the Japanese coast. Four tuffaceous derivatives available are in the order of their increasing hardness; soft tuffaceous mudstone, soft brittle tuffaceous sandstone, fine tuffaceous sandstone and coarse tuffaceous sandstone. With the exception of Barnea, the borers are more commonly found on vertical or inclined surfaces than on horizontal. In Parapholas and Lithophaga, the boring is perpendicular from the mouth to the end of the tube, inclined or more or less curved in Pholadidea and Barnea and inclined and curved in Zirfaea and Jouannetia. In all species, the largest diameter of the hole is near its end where the animal rests. The most of the borings are made so that the living quarters of the animal are intertidal. However, the lower limit of distribution is difficult to determine and living specimens have been recorded at unexpected depths. Pholadidea penita, for example, was dredged from 50 fathoms.

Table 1 charts the borings in the different kinds of substratum. It indicates that Barnea is by far the most common in tuffaceous mudstone although it is found also in soft brittle sandstone. Zirfaea occurs both in tuffaceous mudstone and in fine tuffaceous sandstone; Pholadidea is rare in tuffaceous mudstone but common in fine tuffaceous sandstone and is present in coarse tuffaceous sandstone; Parapholas is present in fine tuffaceous sandstone and common in coarse tuffaceous sandstone; Jouannetia is rare in tuffaceous mudstone and fine tuffaceous sandstone; Lithophaga is present in tuffaceous mudstone, common in fine tuffaceous sandstone and rare in coarse tuffaceous sandstone.

Otuka, Yanosuke. Lower Pleistocene Marine Invasion and Pleistocene Terraces on the Pacific Coast of Japan. Imperial Academy, Tokyo, Proc., Vol. 9, pp. 635-638, text map, December, 1933.

Elephas namadicus naumanni Makiyama is, in Japan, a zone marker of the lower Pleistocene. Elephas-bearing beds are known in the Boso peninsula, at Saharma on the Pacific coast of southwest Japan, in the scarps of the Musasino terrace near Tokyo and Yokohama and in the Otu beds south of Tokyo. In the Otu beds, marine shells are associated with the Elephant remains and a similar marine fauna occurs in other terrace deposits. A Pacific marine invasion in early Pleistocene time is postulated by Otuka.

Endo, Rokuro. Method of Boring of Testing the Formation in Kita-Daito-Zima. Geol. and Paleon. Institute, Tohoku Imperial Univ., Rept. No. 14, 1935. (Japanese).

The technical description of the drilling is prefaced by Professor Yabe of Tohoku Imperial University. It was made under the direction of Professor Yabe as a part of the investigation of the coral reef problem. A series of reports concerning the geology of the island are to be published. The

following reports are listed as already completed:

1. Yabe, H. and Sugiyama, T. Subfossil Gizzard Stones, probably of birds, found in the Phosphate Deposits of Kita-Daito-Zima. Proc. Imperial Acad., X, No. 6, pp. 361-364, 1934.

2. Sugiyama, T. On the Boring at Kita-Daito-Zima. Japanese Report of the Geological and Paleontological Institute of Tohoku Imperial University, No. 11, 1934.

Tayama, Risaburo. Terrain, Geology and Coral Reefs of Palau or Peleu Group: Dept. Geol. and Paleon., Tohoku Imperial Univ., No. 18, 1935. 67 pp., 18 sketches, 3 geol. maps, 15 scenic pls. with 58 figs. (Japanese, no abstract but occasional key words and chapter heads in English.)

Over 100 islands, among them 12 main islands, are included in the Palau group. The geography, structural features and areal geology of Babeldaob (Palau Island proper) are considered at length in a later report by the same author (1939). The 12 main islands and some of the islets are considered in the present report but the information is, in the main, stratigraphic.

On Korror Island, which is in part volcanic and in part limestone, the wave cut terrace at the foot of the cliffs merges into the reef flat at the outer margin. Mangrove swamps are numerous in the volcanic area but are restricted to it. Three other organic zones have been recognized on the reef flat: the Zostera, the Halimeda, and the Montipora ramosa zones. Lateritic clay containing fish teeth and shells are said to have been found by a Buddhist priest on a lower terrace in the volcanic area. Narrow sandy beaches with palm trees border the shallow sheltered shores on the oceanic side of the limestone areas. Alakabesan Island, of volcanic origin, is fringed with mangrove swamps along the eastern coast. On Gualdowaisi Island, the mangroves are limited to the small area of volcanic rock. Olopshakar and Galangol Islands form the northeastern rampart of Palau harbor. Interesting observations have been made on coral growth in a passage opened near the north end. Reef building corals flourish on the north wall where they receive the optimum sunlight; on the south wall, facing the north, the growth is less abundant and the corals less vigorous. The limestone through which the passage was dug is light pink or yellow, rich in finely preserved reef building corals together with some shells and Foraminifera. On Wulktarble a good molluscan fauna was recovered from the limestone near the light house.

The form and development of the coral reefs in the Palau group are discussed. The sea level coral reefs make great barrier reefs 125 km. from north to south with a maximum width of 27 km. The inner reefs surround the limestone islands in the south and the volcanic islands in the north, and are developed continuously around Babeldaob. The reef flat reaches a maximum width of 2 km., is nearly level, and thinly covered with coral sand and clay. The corals are most vigorous on the outer slope of the reef; toward the inner edge, in the Halimeda and Zostera zones, the individuals are few and in large part smothered by calcareous algae. The inner reefs are more commonly interrupted in the limestone zone than in that of the volcanic rocks. The outer

reef flat on the west side of the islands averages about 1800 meters wide and the passes are few and narrow. On the east side, the average width of the reef is only 800 meters, and is broken into many segments connected by shallow reefs 5 to 10 meters wide. The single pass lies in the south.

The development of the reefs on the western and the eastern sides of the central island is asymmetrical. On the west side, the reefs are wide and relatively distant from the coast line; on the east side, they are narrow and near shore. The dominant wind is the east wind and wave destruction is stronger on the east coast than it is on the west. On the west side, in the quiet water, the reef develops seaward freely; on the east side, it is broken by the strong waves and beaten back toward the island. A second reason for the asymmetric development of the reefs is the difference in the dips of the foundation rock on the east and the west sides.

Palau harbour is a lagoon within a lagoon. The volcanic island, Marakar, is surrounded by the limestone islands, Olopshakar, Galangol and Wulkatarble. The deepest parts of the main lagoon lie at the entrance to the inner reef passage where the outer reef is incomplete, suggesting that the depth is related to the tidal currents. The theory is also advanced that coral and algal growth are stimulated at the margin of the channels and that the increased growth serves to canalize the current.

The theories of Semper and Davis on the origin of the islands are discussed but accepted only in part.

A bibliography of 19 titles concludes the report: 10 articles are written in Japanese, 6 in German, 2 in English and 1 in French.

Tayama, Risaburo. Table Reefs, a Particular Type of Coral Reefs. Imperial Acad. Tokyo, Proc., Vol. 11, No. 7, pp. 268-270, 2 text figs., 2 tables, July 1935. (English.)

Coral reefs are generally classified as fringing reefs, barrier reefs and atolls, but the table reefs do not fall into any one of those categories, The table reefs are small, isolated, nearly flat reefs or islands built of coral sand, gravel, and foraminiferal sand. They are usually round or oval rather than elongated and are characterized by the absence of a lagoon. Tobi and Sonsorol are typical table reefs. Commonly, a boulder rim surrounds the island, and the central part is filled with phosphate deposits. The reefs are washed by the sea at high tide but are exposed at low water. Building corals, such as Porites, Favia, Acropora, and Leptoria, favor the intertidal top surface and occasional nullipore ridges rise on the outer margin to a height of less than one meter. Although the reefs are so insignificant in relative height above the sea, the reef bases rise from ocean depths of two to four thousand meters. In profile they resemble volcanic conides, with the slope steep near sea level but gradually flattening toward the ocean floor. The "Shoal Reefs" of Mollengraaff and Faustino and the "Plaatriffes" of Niermeyer form on continental or insular shelves and may be considered as modifications of either barrier or fringing reefs.

Nearly all the islands of the South Marianas, including Tinian and Saipan, may be regarded as elevated table reefs. They are flat topped and built of

horizontal coral or Halimeda-limestone. Feis Island in the Carolines has been regarded as an elevated atoll, but it lacks the central depression indicative of a former lagoon and seems more probably an elevated table reef.

Two possible theories of genesis are advanced: (1) The Table Reefs represent a type of atolls in the process of transformation into the "Extinguished Reefs"; (2) the Table Reef corals are building on the summits of volcanoes submerged at a favorable depth. Supply Reef in the North Marianas serves as a good illustration of such an assumption.

The first table gives the measurements, length, width, and circumference, and the height above the ocean floor of 16 of the Pacific Islands. The second table gives the number of sea level, elevated, and submarine table reefs in the Marianas, Palau, Caroline, and Marshall groups.

Tayama, Risaburo. Distribution of Coral Reefs in the South Sea. Imperial Acad. Tokyo, Proc., Vol. 11, No. 8, pp. 326-328, 1 map, October 1935. (English.)

The Japanese Mandated Islands are separable into two larger groups, the West and the East; and three smaller groups in each major group, the North Marianas, the South Marianas, and Palau in the western; and the Carolines, Marshalls, and the Central Islands in the eastern group.

The Western Mandated Islands:

1. The North Mariana group. - Only fringing and submerged table reefs found; the former are mostly built on the slope of extinct volcanoes and are in the early stages of formation.

2. The South Mariana group. - Nearly all the reefs are elevated table reefs, flat topped, and built of coral limestone on an apparently flat base.

3. The Palau group. - In the Yap Islands, the reefs are full-grown and fringing; in the Palau Islands elevated barrier reefs and atolls are developed together with Recent sea level reefs of various types; and in the Tobi Islands the table reefs flourish.

The Eastern Mandated Islands:

1. The Caroline group. - Eighty of the 160 coral reefs known from the South Sea are in the Carolines. Submerged atolls and submerged table reefs are found only in the West Carolines; of the sea level atolls 15 belong to the West Carolines, 17 to the East Carolines.

2. The Marshall group. - Eighty-one of the coral reefs are of the atoll type.

3. The Central group. - Only small atolls with shallow lagoons are known from the Central group.

The lack of uniformity in the distribution of the coral reefs in the different island groups is difficult to reconcile with Daly's Glacial-Control-Theory. On the other hand, the assumption of Darwin's Subsidence Theory offers a reasonable explanation. The three western groups of the South Sea Islands are built on zones of uplift, and the three eastern groups on zones of subsidence; the maximum uplift is recorded in the South Marianas, and the

maximum subsidence at the West Carolines. Whether the asymmetrical development of coral reefs along the east and west sides of some of the islands in the West group is due to block tilting as Hobbs believes, or to some prevailing meteorological and oceanographical conditions affecting the east and west sides diversely is still an open question.

The map indicates roughly the bottom features of the South Pacific area.

Yabe, Hisakatsu and Sugiyama, Toshio. Revised Lists of the Reef Corals from the Japanese Seas and of the Fossil Reef Corals of the Raised Reefs and the Ryukyu Limestone of Japan. Geol. Society Japan, Jour., Vol. 42, No. 502, pp. 379-403, 2 plates, July 20, 1935. (In English).

Corals from several localities are listed:

(1) List of the Reef Corals found in the Raised Coral Reef of Noma and the Raised Beach Deposits of Mera (45 species and varieties);
(2) List of the Reef Corals found in the Raised Coral Reef of Kikai-zima and Kume-sima, Ryukyu Island (37 species);
(3) List of the Reef Corals found in the Raised Coral Reef of Taiwan (64 species);
(4) List of the Reef Corals found in the Ryukyu Island (53 species);
(5) List of the Corals found in the Ryukyu Limestone of Taiwan (31 species);
(6) List of the Reef-Corals living in the Japanese Seas (40 species and varieties).

Two new genera are described and excellently figured.

Hiro, F. Notes on the Molluscan Fauna of Palao. 1, Common Shells and their Habitats. The Venus, Vol. 6, No. 1, pp. 31-43, 1936. (Japanese).

Hiro, F. Cirripeds of the Palao Islands. Palao Trop. Biol. Station Studies, No. 1, pp. 37-72, 1937.

Intertidal barnacles depend for their distribution more or less on the nature of the shore rocks. Salinity, wave strength and tidal current also influence their distribution.

Abe, N., Eguchi, M., and Hiro, F. Preliminary Survey of the Coral Reef of Iwayama Bay, Palao. Palao Trop. Biol. Station Studies, No. 1, pp. 17-35, 1937.

The geology and topography of the bay are discussed. Observations on coral reefs, depth of lagoons, direction of currents, etc., are included. A map of the bay accompanies the article.

Hiro, F. Studies on the Animals Inhabiting Reef Corals. I. Hapalocarcinus and Cyrptochirus. Palao Trop. Biol. Station Studies, No. 1, pp. 137-154, 1937.

Galls of Hapalocarcinus were found on 8 species of corals. The observations of the author generally agree with those of Potts on the coral infestin crustaceans.

Abe, N. Ecological Survey of Iwayama Bay, Palao. Palao Trop. Biol. Station Studies, No. 2, pp. 217-324, 1938.

The chief investigations include quantitative studies of associations on sandy flats, the distribution of corals, and the influence of current on the direction of their growth.

Eguchi, M. A Systematic Study of the Reef-Building Corals of the Palao Islands. Palao Trop. Biol. Station Studies, No. 3, pp. 325-390, 1938.

A large number of corals is listed together with their distributional records.

Hiro, F. Studies on the Animals Inhabiting Reef Corals. II. Cirripeds of the Genera Creusia and Pyrgoma. Palao Trop. Biol. Station Studies, No. 3, pp. 391-416, 1938.

Tanita, Senji. On the Duration of Life of Littorivaga brevicula and L. millegrana. Venus, Mal. Soc. Japan, Vol. 8, pp. 88-97, June 1938. (Japanese with English abstract.)

Littorivaga brevicula and L. millegrana are commonly attached to rocks at or above high water mark and are more numerous under the direct sun than in wet places under high-water neaps. Experiments were made on their longevity under certain unfavorable conditions. In the air of a room, they lived from 2 to 2.5 months. The size of the animal was not correlated with the duration of life.

In dilute and concentrated sea water, they survived longer than Nerita japonica, a species of the littoral zone. When completely submerged in normal sea water, they continued to live for more than four months.

The optimum temperature for their activity seemed to be between 20° and 25° Centigrade. The high critical temperature was about 45° for Littorivaga brevicula and 50° for L. millegrana. When submerged for only a short period, they could endure 51° and 55° respectively. The low critical temperature was not determined but they lived for more than 20 hours under 0° to -5°. Littorivaga brevicula was the first to recover.

Asano, Kiyosi. Limestones of the South Sea Islands under the Japanese Mandate Jubilee Publication in the Commemoration of Professor H. Yabe, M. I. A. Sixtieth Birthday, Vol. 1, pp. 537-550, pls. 27, 28; 5 charts, 2 text figs., 1939; ibid, (Abstract in English), Japanese Jour. Geol. and Geog., Trans., Vol. 17, p. 58, Oct. 1940.

The limestones of the region are paleontologically as well as stratigraphically separable into six groups. The older limestones do not occur

in the Carolines and Marshalls, but the Recent and raised reef limestones are common in those islands.

Le limestone: The foraminiferal fauna includes Biplanispira, Pellatispira, Discocyclina, Asterocyclina, Spiroclypeus, and small Camerina; large Camerina and Assilina are not recorded. The limestone is probably of upper Eocene age and is the oldest fossiliferous formation not only in Saipan but in the whole Mariana and Palau groups.

Lo_1 limestone: The limestone is so impure that it may be called calcareous sandstone. It is known only in Saipan and is interbedded or included in nodules in the upper sandy and tuffaceous conglomerate complex. Eulepidina, Spiroclypeus, and Miogypsinoides are among the characteristic Foraminifera and indicate an Oligocene or Aquitanian age.

Lo_2 limestone: The limestone grades laterally into a complex of tuff, sandstone, and soft shale. The foraminiferal fauna is similar to that of Lo_1 but includes in addition Miogypsina, Nephrolepidina, and Trillina, a typical Aquitanian assemblage. Similar limestones have been recorded in Tinian, Rota, and Medinidia.

Lm limestone: Nephrolepidina, Cyclocypeus, Miogypsina, Heterostegina, and Operculina characterize the Burdigalian limestone found in Saipan, Tinian, Rota, Medinidia, and Yap. Eulepidina and Spiroclypeus are absent.

Lp_1 and Lp_2 limestones: The Lp limestones are of Plio-Pleistocene age and contain only living species of Foraminifera. The later limestone usually retains its horizontal position and forms the terraces distinctive of the islands.

Hanzawa, Shoshiro. On the Occurrence of Acervulina, an Encrusting Form of Foraminfera in the Jurassic Torinosu Limestone from the Kwanto Mountainland, Central Japan. Geol. Soc. Japan, Jour., Vol. 46, No. 547, April 20, 1939. Paleon. Soc. Japan, Trans., No. 82, pp. 201-203, pl. 12, no date given. (English with Japanese summary.)

Living Acervulina are common in the warm and shallow waters of the Pacific, Atlantic, Indian, and Mediterranean and also in various Tertiary beds. Before the discovery in the Jurassic of Japan, there was no record of it in rocks older than the Cretaceous. In its rare occurrence in the Jurassic it is intergrown with calcareous algae.

Hatai, Kotora M. and Nisiyama, Syozo. Remarks on Certain Fossils from the Borderland of the Japan Sea. Japanese Journal Geol. and Geog., Vol. 16, pp. 123-154, pl. 9, July 1939. (English.)

The collections considered were made from two localities in Kaga, one in Ettyu, two in Etigo, and one from North Tycsen, all on the borderland of the Japan Sea. The Kaga fossils belong to the Onma beds of Pliocene age; the single locality in Ettyu from the Zyono beds of Pliocene age; the two localities in Etigo to the Alternation beds or to the Siiya series of middle Neogene

age; the fossils from north Tyosen from the Heiroku beds (lower Miocene) of the Meisen series. Twenty-three species are discussed, some of them, such as Anadara trilineata (Conrad) and Anadara amicula (Yokoyama), at considerable length. Five new species and subspecies are described and figured.

Koriba, Kwan, and Miki, Shigeru. On Paleodictyon and Fossil Hydrodictyon. Jubilee Publication in the Commemoration of Professor H. Yabe, M.I.A. Sixtieth Birthday, Vol. 1, pp. 55-65, pls. 4, 5; 7 text figs., 1939.

Paleodictyon was described by Meneghini in 1851 and correctly referred to the algae. Later, because of its flat, hexagonally netted impressions it was transferred to various invertebrate groups, including the sponges, corals, and bryozoans. It has also been interpreted as a cast of a Sigillarian, the impressions of honeycomb, the spawn of marine gastropods, as a tadpole nest, the casts of reptilian scales or the result of ripple marks formed under peculiar conditions. Most, if not all, of the earlier specimens were not in place but encrusted loose stones in the river beds. Recently, material was found adhering to the under surface of sandstones overlying shale beds, indicating that the algae lived on the surface of the lagoonal and estuarine muds and were buried in flood by a deep sand layer. The creep trace of annelids or gastropods are commonly associated.

Paleodictyon is recorded in Japan and Europe from the Jurassic to the Upper Tertiary. The habitat was the brackish water of lagoons and estuaries probably on the north shore of the Tethyan sea. The living species of the family to which Paleodictyon is referred all live in fresh, well-lighted water. Paleodictyon was not anchored to the substratum, and the impact of the disturbed estuarine and lagoonal waters is recorded in the frayed margins of the colony walls. The fresh water pools in which the recent allied forms are found offer less of a hazard, and possibly for that reason the more turbulent brackish waters have been abandoned.

Miino, Hirosi. The Geology, Topography, and Marine Deposits of Kyuroku-Sima and its vicinity, Nisi-Tugar-gun, Aomori Prefecture, Northeast Japan. Jubilee Publication in the Commemoration of Professor H. Yabe, M.I.A. Sixtieth Birthday, Vol. 1, pp. 589-612, pls. 31, 32; 5 text figs; 8 tables, 1939.

Kyuroku-sima is an islet group of four small rocky protuberances in the northern part of the Japan Sea. The foundation rocks include andesite, agglomerate, and green tuff, with intercalated shale and sandstone in the lower part of the section and well-stratified tuffaceous sandstone and shale and coarse-grained, incoherent sandstone in the upper part of the section. The surface rock in the southeastern part of the largest island is a white tuff or tuffaceous sandstone, sparsely diatomaceous, and in faulted contact with the olivine-bearing pyroxene-andesite agglomerate. Similar agglomerate is found in the port of Fukaura on the nearby mainland and embedded in white tuff on the sea bottom. The rocks are widely exposed, for the surface is bare of soil and vegetation. Cliffs about two meters high surround the islands. The surface of the three smallest islands is completely covered by the high seas.

Kyuroku-sima rises from a bank elongated along the northwest-southeast axis and measures 8 kil. at the 200-meter contour line. To the north, west, and south the bottom drops to 1,000 meters, but the greatest depth between the islets and the mainland on the east is 500 meters. Between Kyuroku-sima and the mainland to the southeast the bank of Dansiti-ne rises to 140 meters below the surface of the water. Down to 200 meters, the broad continental shelf is covered, for the most part, with sand; below 200 meters, with mud. Several shell and gravel stations were recorded between Dansiti-ne and the mainland. The rocks dredged from the continental shelf are all closely similar to each other, and to rocks of Neogene age outcropping on the mainland. The gravels from the sea bottom around Kyuroku-sima are more angular than those from the continental shelf. Marine organisms and occasional algae may be adherent, indicating that they have not been buried in either sand or mud. The gravels are derivatives of rocks similar to those of which Kyuroku-sima is built and have probably been torn away by vigorous wave action and transported by strong oceanic currents. Ophiurans were the most abundant of the invertebrates dredged. Molluscan shells and brachiopods were also common. The abalone is the most valuable fisheries product, but it is limited by the distribution of a certain species of sea grass. Sea life is most abundant where bed rock is exposed along the sea bottom. The banks should prove to be excellent fishing grounds for those animals that feed on shell fish.

Nomura, Sitihei and Hatai, Kotora M. On some Fossils from Akita Prefecture, Northeast Honshu, Japan. Japanese Journal, Geol. and Geog., Vol. 16, pp. 39-64, 5 text figs., July 1939. (English.)

Mollusca were collected at a number of localities in the Akita Prefecture from a sand and shale series included under the Taya sandstone. Three fauna horizons were recognized. The overlying sand shales are tuffaceous, gray, rather soft and sparsely fossiliferous. The underlying black shales with which the Taya sandstone is in faulted contact are soft and almost completely barren. It is probable that the sedimentary series referred to the Taya sandstone is of Pontian age, and that this horizon marks the final stage of the Miocene and the initial stage of the Pliocene fauna. Seventy-four species of Mollusca are cited with stratigraphic and distributional information. Five of the seventy-four are new and are described and figured. The fauna includes also twenty-five species of brachiopods.

Shimakura, Misaburo, and Matai, Kotora M. On a Fossil Species of Lingula from Hirobuti-mura, Miyagi-ken. Geol. Soc. Japan, Jour., Vol. 46, No. 550, pp. 401-405 (in English; summary in Japanese); 1 sketch map; 1 pl., 1939.

Records of Lingula from the Middle and Upper Tertiary and the younger deposits of Japan are very few, and the majority of those records are from the Pleistocene deposits. Certain inferences on the current ecological conditions may be drawn. The genus is confined in the present day to tropical and warm-temperate seas. In certain bays and estuaries of southern Japan the animals live in burrows 2 to 12 inches long and move up and down the holes by means of the highly contractile peduncle. They are not affected by brackish water or by water so foul from decomposing organic matter that the burrowing Mollusca are unable to survive. They may be exposed on intertidal flats for hours with no apparent injury. They are characteristic of waters from 0 to

10 fathoms deep and of either sandy or muddy bottoms.

The species under discussion, Lingula sp. cf. L. unguis (Linnaeus), is abundant in layers of loose sandstone intercalated in the lower part of the Sue sandy shale beds. The Sue beds are correlated with the Tatunokuti beds in Sendai and its environs and with the Yusima beds of the Itinoseki-Wakayanagi district and are referred to the Pliocene.

Tayama, Risaburo. Preliminary Report on Geology and Mineral Resources of Babeldaob Island (Palau Island proper). Bull. Trop. Industry Institute Palau, South Sea Islands, Japan, Vol. 3, pp. 1-19, 4 text sketches, 1 pl. (geol. map); July 1939. [Abstract, Japanese Jour. Geol and Geog., Vol. 17, pp. 61, 62, 1940.] A more detailed treatment of a part of the area covered by the same author in "Terrain, Geology and Coral Reefs of Palau or Peleu Group," 1935. (Japanese except for a few key words and the map legend translated into English.)

Babeldaob or Palau Island proper is the central island of the Palau Barrier Reef. It is a plateau of 370 sq. km., broken by a few low hills, the highest reaching 240 meters. The coast line is deeply indented.

The following beds have been mapped:

1. Recent limestone.
2. Raised beach deposit.
3. Terrace deposit.
4. Palau* limestone
5. Airai lignite-bearing beds.
6. Almonogui agglomerate.
7. Aimiriiki agglomerate.
8. Galdog beds.
9. Babeldaob agglomerate.
10. Gamusetu agglomerate.

* Spellings from Naito list.

1. Recent limestone. - Masses of coral, the interstices filled with foraminiferal sands, form a limestone which outcrops at low tide at a few places along the beach. The width is only 2 to 3 meters, and the angle of deposition about 5°.

2. Raised beach deposit. - An intermittent deposit of coral, broken shell foraminiferal sands and muds derived from estuarine and river flood plains reach a maximum width along the shore of about 500 meters. The surface of deposition is approximately level along the foot of the plateau. The thickness at the inner margin is about 3 meters, at the outer shore margin about 1 meter.

3. Terrace deposits. - These are, in the main river, gravels raised 5 to 10 meters above the water level of the stream. The nature of the gravels varies with the drainage basin. Many of the gravels are quartz trachyte, others such as those in the valley of the new water supply for the Tropical Industry Institute are derived from andesite only. Clay and sandy clay mixed with gravel and bauxite commonly overlie the lower gravels.

4. Palau limestone. - The Palau limestone is a raised coral reef limestone, probably a barrier reef of the past. Its distribution is restricted to the southern end of the island and the nearby islets and may be traced from some distance at sea by the heavy forest growth which it supports, and which is in sharp contrast to the barrenness of the red andesite. The limestone is underlain by a basal conglomerate and interbedded sandstone containing Acropora, together with shales and marls laid down on a 10° slope. On exposure the coral limestone changes color from green and yellowish brown to dark yellow and white.

5. Airai lignite-bearing beds. - Some at least of the lignite beds were thoroughly investigated at the time of the German occupation. In the southern part of Mesara Island a lignitic clay overlies a sand and gravel bed which in turn overlies the brown lignite. The thickness of the lignite is 4 meters, the strike N. 20° E., and the dip 10°E. Along the western coast 5 beds of good and poor lignite are interstratified with lignitic shale. On the east coast the beds are mostly sandstone and conglomerates with some lignitic shale but no brown lignite. Near the Tropical Industry Institute the brown lignite bed is exposed, and below it two fossiliferous beds separated by a clay stone. The upper fossiliferous bed is derived largely from coral and includes a few shells toward the base. The lower fossiliferous bed includes shell remains in large numbers and a few corals. Other beds of lignitic shale and lignite outcrop below the fossiliferous beds. The outcrops show a considerable variation in the sequence of the sedimentaries and in the thickness of the lignite seams. For the most part, the beds are nearly horizontal, and the dip rarely exceeds 10°. The relation to the overlying Palau limestone is not clear, but they seem to be separated by an ill-defined unconformity.

6. Almonogui agglomerate. - This is the youngest of the three agglomerates which were previously included under the single name of the Agglomerate rock of Babeldaob Island. It is made up for the most part of augite and pyroxene andesite with occasional interbedded tuffs and outcrops locally in the form of hogbacks and monadnocks. The dip is usually less than 10°. As the Airai lignite beds have not been found within the area of distribution of the agglomerate, there is no direct evidence of their relationship. No mineral deposit nor fossil has been recorded in the Almonogui.

7. Amiriiki Agglomerate. - The rock is chiefly an agglomerate of augite proxene andesite and an agglomeratic tuff. Amygdoloidal andesite tuffaceous shale similar to that in the underlying Galdog beds, and limestone nodules are included in the lower part of the tuff. Foraminifera are reported from the limestone. There is some evidence of a faulted contact with the Almonogui agglomerate. No unconformity with the underlying Galdog beds has been noted, but such a relationship is indicated by their distribution. A dip of 30° is not unusual.

8. Galdog beds. - Alternating sandstone, shale, tuffaceous shale, marl, and agglomerate are included in the Galdog beds. The sea cliffs offer excellent and extersive exposures, one of them in Ogiwaru reaching 40 meters in height. In the cliff exposures the marl beds show the greatest resistance and stand out as ledges. Some of the sandstone are ripple marked, and the shales include fossils of a "moss like creature". On weathering the beds assume a higher coloring of reds, yellows and purple. The upper part of the

cliff section at the Forest experimental Station includes a thick bed of sandstone containing blocks of fossiliferous limestone. Pellatispira and Discocyclina have been identified. Faulting with dips up to 70° have been observed. The fragments of amygdoloidal andesite in the basal conglomerate indicates an unconformity with the underlying Babeldaob agglomerate, although no exposure of such a break is known.

9. Babeldoab agglomerate. - The dark green augite and pyroxene andesite which make up the greater part of the Babeldaob agglomerate occupies about half the island. The pyroxene andesite is veined with quartz and the numerous fractures are filled with limestone and shale and more rarely with sandstone. Lithothamnium and Amphistegina have been recovered from the limestone. An agglomerate of amygdaloidal andesite, nearly shale, and coral limestone containing Eomontipora is of local occurrence in the lower part of the section. In some sections the basal beds of the Babeldaob are agglomerates of hornblende and quartz andesites or dacite. The dip usually exceeds 20°.

10. Gamusetu agglomerate. - The oldest known beds on the island are of volcanic origin and include a green agglomerate of quartz trachyte, quartz andesite, and probably quartz porphyry, mica porphyry, and dacite.

Correlation of the Babeldoab beds with those of related islands especially Saipan, are fairly well established. There are no differences in the Recent limestone and raised beach deposits of Babeldoab and those of Saipan. The terrace deposits of the two islands also are similar and of Pleistocene age. The Palau limestone is the equivalent of the Mariana limestone of Saipan and of the Ryuku limestone of Formosa and belongs to the Pliocene-Pleistocene series. The Airi lignite bed includes two species of plants, a pine and an oak which grow in the surrounding country, and it has been referred by Mr. Eudo to the Pliocene series. The Almonogui agglomerate has no counterpart in Saipan, but the Tomii agglomerate of Yap Island is comparable in that both are composed largely of augite and andesite, are nonfossiliferous, and unveined. The Almonogui agglomerate like the Tomii is referred to the Miocene. The Aimiriiki, Galdog, and Babeldoab agglomerates were all derived, in part at least, from submarine volcanic eruptions, all contain limestone inclusions, and in all of them the inclusions are considered contemporaneous with the bed in which they are found. The limestone inclusions in the Galdog beds carry Foraminifera of Eocene age. The Aimiriiki agglomerate above and the Babeldoab agglomerate below the Galdog beds may also be referable to the Eocene. The Gamusetu agglomerate is similar lithologically to the quartz trachyte of Mt. Sankau in Saipan. Both are older than the overlying andesite, but they are not dated by direct evidence of any kind.

Certain scattered observations on the dips have been reported and inferences made.

Investigations of the mineral resources were in progress in 1939. Mention is made of gold, zinc blende, pyrite, marcasite, copper pyrite, stibnite, manganese, bauxite, which is discussed at some length, and limonite and hematite. The nonmetallic ores include phosphorus, lignite, and quartz; the useful rocks, fire clay, limestone, marble, and tuff. The gold, zinc blende, pyrite, and copper pyrite are associated with the quartz veins in the Babeldoab

agglomerate. Pyrite is reported also from the Gamusetu agglomerate. Marcasite is associated with the lignitic beds. The Babeldoab and Galdog agglomerates form the mother rock of the brown bauxite ore, the Airi lignite-bearing bed, the mother rock of the white bauxite ore. Limonite and hematite are associated with the bauxite in the surface bed, but they are laterization products and are not developed below a surficial zone about two feet thick. The sources of the phosphorus are the cave deposits of bat guano. The lignite is, for the most part, of poor quality, but the upper meter of the 4-meter bed on Nerasaka Island may be used as a local source of fuel. Associated with the lignite is a clay with strong fire resistant properties, but lacking uniformity of strength. The upper part of the Palau limestone is used for road ballast, but the lower part contains too much clay. The so-called marble is a nearly horizontal bed in the Palau limestone, which is almost exhausted by the demand for the stone coin of Yap. Unveined andesitic tuff in the Almonogui, Airimiiki, Galdog, and Babeldoab agglomerates are a possible source of building material.

Tayama, Risaburo. Terraces of the South Sea Islands under the Japanese Mandate, Imp. Acad. Tokyo, Proc., Vol. 15, No. 5, pp. 139-141, 1 correlation table, May, 1939. (English); ibid, Japanese Jour. Geol. and Geog., Vol. 17, Abstracts, p. 51, Oct. 1940.

All of the Japanese Mandated Islands are terraced. The terraces are the most numerous (16), and the best-developed on Rota of the South Mariana group. However, the upper terraces on the islands of the East Caroline group are old basalt flows and are not included in the present discussion.

The correlation of the depositional terraces on different islands is not difficult, if the islands in question are built up on the submarine ridge. Even if more than one ridge is involved, a widely distributed group of terraces built of elevated coral reef limestone of Plio-Pleistocene age serves as a dependable reference plane.

The following succession has thus been established:

Holocene	Recent limestone and other deposits. Raised beach deposits and younger raised coral reef limestone.
	Unconformity
	Older raised coral reef limestone
Pleistocene	Unconformity. Terrace deposits.
	Unconformity.
Plio-Pleistocene	Mariana-Palau limestone
	Halimeda formation.
	Unconformity.
Miocene	Nephrelepidena formation.
	Unconformity.
	Eulepidina formation.

Oligocene	Unconformity.
	Densinyama formation.
	Unconformity.
Eocene	Camerina formation.
	Unconformity.
Pre-Tertiary	Pre-Tertiary formation.

The pre-Halimeda terraces are restricted to the Saipan Islands of the South Mariana group. The terrace on which the Halimeda formation is laid down is nearly equally developed in the South Marianas, Palau, and Yap, and in some of the East Carolines. Both the Mariana terrace--the surface of the Mariana limestone and of its equivalent, the Palau limestone--and the Pelilieu terrace, the surface of the older raised coral reef limestone are best displayed in the western island groups. The post-Pelilieu terrace, the younger raised coral reef limestone terrace, is raised about 1 to 2 meters above the reef flat on all the islands. The pre-Mariana, Mariana, and Pelilieu terraces are developed at different heights in different islands and serve as datum planes indicating the amount of crustal movement suffered by the separate islands. By the same token the uniform development of the post-Pelilieu terrace indicates the recent change in relative land and sea levels throughout the area.

In the South Mariana group, where terraces are well defined, drowned valleys have not been observed, apron reefs and fringing reefs are developed, but few, if any, barrier reefs. In the East Caroline group, where terraces are poorly defined, drowned valleys are well developed, and the sea level coral reefs take the form of barrier reefs and near atolls.

Crustal movement is a decisive factor in the form of growth of the coral reef.

Tayama, Risaburo. Correlation of the Formations in the South Sea Islands. Geol. Soc. Japan, Jour., Vol. 46, pp. 345-348, 1939. (Japanese); ibid, Abstract, Japanese Journal Geol. and Geog., Trans. and Abstracts, Vol. 17, Nos. 1 and 2, 3 of abstracts, March, 1940. (English).

6. Plio-Pleistocene Mariana-Palau raised coral reef. This is correlated with the Riukiu limestone in Taiwan and the Riukius.

5. Pliocene Halimeda group. (lignite bearing beds in the Palaus limestones in the Marianas.)

4. Miocene Nephrolepidina group. (Limestone in Mariana and agglomerate and sandy mudstone in Yap.)

3. Oligocene Eulepidina group. (Tuffaceous and calcareous facies in Mariana.)

2. Eocene Camerina limestone. (Tuff agglomerate in Palau and Mariana.)

1. Pre-Tertiary Yap formation (Amphibolite in Yap. The rock is also represented by pebbles in the Tertiary formations on other islands.)

There are also terrace deposits and old raised reef limestone of Pleistocene age and the young raised reef limestone, elevated shore deposits and recent limestone of Holocene age.

Hanzawa, Shoshiro. Micropaleontological Studies of Drill Cores from a Deep Well in Kita-Daito-Zima (North Borodinao Island): Jubilee Publication in the commemoration of Prof. H. Yabe's 60th Birthday, Vol. 2, pp. 755-802, 5 text figs., pls. 39-42, 1940.

The dedication of this paper to Prof. Yabe is particularly happy because the bores from which the material was taken were of his planning, and the whole operation was accomplished under his direction. The bore was begun on March 12, 1934, and shut down at a depth of 209.29 meters on April 24, 1934. Drilling was resumed on January 17, 1936, and completed at 431.67 meters on May 24, 1936. Most of the 1934 boring was through hard limestone; of the 1936 boring, through almost incoherent calcareous sand. No trace of pumice or any other volcanic product was detected in any part of the core. The Foraminifera make up the greater part of the drillings, but reef-building corals, alcyonarian spicules, Bryozoa, Ostracods, Mollusca, echinoid tests and spines, calcareous algae, and fine detrital calcareous sediment were also important constituents. The most of the Foraminifera throughout the length of the core were shallow and warm water inhabitants. Remains of Coccolithophoridae are practically lacking. The limestones from the surface to a depth of 103.49 meters showed a dolomite content from 78.87 percent to 90.45 percent, while that of the samples taken below the 103.49 meter level decreased abruptly, showing only 1.07 percent to 6 percent. However, the dolomite content at 132 meters was 41.31 percent; at 134.86 meters, 70.67 percent, and at 174.18 meters, 87.56 percent. All the cores from the greater depths were almost free from notable dolomite content. Occasional discontinuity in the core was probably caused by subsurface caverns due to dolomitization. For example, only 2.67 meters of core were brought up between 120.38 and 146.43 meters.

The cores obtained in the drilling operations were carefully numbered and preserved. Slices were cut from the median plane of each cylinder and nodule by a lapidary saw. About 900 thin sections, 10 cm. in length were prepared in this way, each section being marked with an arrow indicating the top of the core. Reef corals were reported in many cores to a depth of 209 meters. In only one instance is it noted that the corals were fragmentary.

Description of the drill cores:

Cores, Nos. 1-11 (2.68 meters to 6 meters). Dirty buff, compact, cavernous, dolomitic limestone consisting of reef-building corals, such as Orbicella, Stylophora, and Porites, calcareous algae such as Lithothamnium and Foraminifera (3 determined species).

Cores Nos. 12-141 (6 meters to 26 meters). Dirty buff, hard, cavernous, dolomitic limestone of granular texture, including fragmental tests of Foraminifera (3 determined species), reef-building corals such as Pocillopora,

Porites, Stylophora, Orbicella, and Goniastrea, echinoid spines and calcareous algae such as Lithothamnium and Archaeolithothamnium.

Core No. 142 (26 meters). White, porous, Halimeda-dolomitic limestone, consisting chiefly of Halimeda but Lithothamnium, Amphiroa, Archaeolithothamnium, Porites, Stylophora, and echinoid spines present.

Cores Nos. 143-192 (26.16 meters to 45 meters). Light yellow, hard, cavernous, dolomitic limestone with the same lithologic character and organic content as Cores Nos. 12-141.

Cores Nos. 193-280 (45 meters to 58 meters). White, hard, cavernous, dolomitic limestone consisting mainly of foraminiferal tests (5 determined species) but reef-building corals, such as Porites, and calcareous algae, such as Lithothamnium, Archaeolithothamnium, Amphiroa, Lithophyllum, and Halimeda also present.

Cores Nos. 281-574 (58 meters to 93 meters). White cavernous dolomitic limestone consisting of minute fragments of calcareous algae such as Lithothamnium, Amphiroa, and Archaeolithothamnium, a few Foraminifera (5 determined species), Mollusca, and reef-building corals.

Cores Nos. 575-648 (93 meters to 103.49 meters). White, indurated, cavernous, dolomitic limestone, consisting of Foraminifera (3 determined species), and fragmental remains of Bryozoa, reef-building corals, echinoid spines, and calcareous algae, such as Lithothamnium.

Core No. 649 (103.49 meters to 107.15 meters). Grayish blue, calcareous mud, with numerous well preserved shells of Cardium fragum Linnaeus.

Cores Nos. 650-661 (107.15 to 109.75 meters). White, porous limestone, consisting of Foraminifera (9 determined species), reef-building corals, such as Stylophophora, Porites, etc., echinoid spines, and calcareous algae, such as Lithothamnium and Amphiroa.

Core No. 662 (109.75 meters to 116.41 meters). Grayish blue, calcareous mud containing numerous well preserved shells of Cardium fragum Linnaeus.

Core No. 686 (130 meters). White porous limestone consisting of a few reef-building corals and Foraminifera such as Acervulina inhaerens.

Core No. 691 (135 meters). White, porous dolomitic limestone containing abundant Amphistegina radiata.

Cores Nos. 649-834 (140 meters to 209.26 meters). White porous limestone of granular texture consisting of Foraminifera (19 determined species), reef-building corals such as Stylophora, etc., alcyonarian spicules, Bryozoa, and Lithothamnium, Archaeolithothamnium, and Amphiroa.

Cores Nos. 835-837 (209.26 meters to 211.28 meters). White porous limestone of fine granular texture containing foraminiferal fragments (4 determined species) and other smaller forms.

Cream-colored, incoherent, coarse-grained, calcareous sand consisting mainly of Foraminifera (4 determined species) and triturated calcareous organic remains recovered from 209.26 meters to 302.31 meters.

Core No. 872 (316.36 meters to 318.97 meters). White porous limestone consisting of Foraminifera (3 determined species), Lithothamnium, Amphiroa, and echinoid spines.

Foraminiferal sands similar to those from 209.26 meters to 302.31 meters were recovered from 302.31 meters to 431.67 meters. The species of Foraminifera vary with the depth, although there is no apparent change in the lithology.

Five depth zones have been recognized:

Zone 1 (2.68 meters to 103.49 meters). Indurated dolomitic limestone characterized by a number of living species of Foraminifera common in the shallow waters adjacent to the Ryuku Islands. Acervulina inhaerens is especially abundant in the upper 40 meters, Amphistegina radiata is abundant in the lower 63 meters.

Zone 2 (103.49 meters to 116.49 meters). Grayish blue calcareous mud containing numerous shells of Cardium fragum Linnaeus. A white granular, porous limestone layer containing Foraminifera similar to those of Zone 1 is intercalated in the mud between 107.15 meters and 109.75 meters.

Zone 3 (116.41 meters to 209.26 meters). Pure porous limestone containing the species found in Zones 1 and 2 and in addition a number of other species including the smaller benthonic forms.

Zone 4 (209.26 meters to 394.98 meters). Cream-colored, unconsolidated coarse-grained calcareous sand. Two faunal subzones with their characteristic foraminiferal assemblages have been recognized.

Zone 5 (394.98 meters to 431.67 meters). Cream-colored, incoherent, fine-grained calcareous sand characterized by Miogypsinella borodinensis.

A distribution table of 28 species of Foraminifera is given.

Geological age of the drill cores. - In its lithologic character, as well as its organic content, the dolomitic limestone of Zone 1 resembles the Daito limestone which is regarded as the equivalent of the Ryuku limestone. The lower part of Zone 1 may, however, be referable to a formation distinct from the Daito and older. In any case all of zone 1 is probably younger than the Burdigalian. The sharp contrast in lithologic character and organic content between Zones 2 and 1 and 2 and 3 suggest a significant stratigraphic hiatus. The relationships of the Foraminifera indicate that Zones 3 and 4 are referable to the Aquitanian and Zone 5 to the Chattian.

An extensive systematic study and revision of the classification of the Subfamily Myogypsininae follows. The known species are referred to their respective genera in the new classification, and a chart is drawn showing the

phylogenetic relation and the stratigraphic distribution of the genera. Several old species of Foraminifera are discussed at length, and five new species and varieties are described and beautifully figured.

A bibliography of 92 entries concludes the report.

Hatai, Kotora M., and Yamamoto, Syogo. Characteristic Features of the Yusima Molluscan Fauna. Inst. Geol. Paleon., Tohoku Imperial Univ., Sendai; Paleon. Soc. Japan, Trans., No. 113, pp. 468 /72/-473 /77/ (in English, summary in Japanese), 1940; ibid, (Abstract in English), Japanese Jour. Geol. and Geog., Trans., Vol. 18, p.22, July 1941.

The characteristic Yusima fossils include Ostrea gigas Thumberg, locally the reef building, the large and heavy Anadara tatunokutiensis (Nomura and Hatai), Pecten takahashii Yokoyama, an excellent zone marker, lucinoids, the large Cardium pseudofastosum Nomura, several species of Macoma, and the burrowing forms, Panope and Mya. The bottom must have been soft and the materials relatively fine. The general assemblage and especially the prominence of Macoma indicate cooler water than the Recent seas at a similar latitude. The depth of the water probably did not exceed 10 meters. The oyster beds may have flourished under more shallow and even intertidal conditions.

The shells are, for the most part, moderately heavy, well formed, and unbroken indicating deposition in quiet waters. The number of species is relatively small, the number of individuals commonly large and almost exclusively bivalves. Apparently bottom and temperature conditions were unfavorable to the carniverous gastropods and to many of the pelecypods, but the few species that were able to maintain themselves under the prevailing conditions could do so with little competition.

The Yusima fauna is referred to the lower Pliocene and correlated with the Sue shale in which Lingula sp. cf. L. unguis (Linnaeus) is locally abundant.

Oinomikado, Tunetura. Tertiary Foraminifera from the Koguti Formation and the Osawa Limestone in the Niitu Oil Field, Niigata Prefecture: Paleon. Soc. Japan, Trans., No. 119, pp. 14-16, text figs. 1a, 1b. 1940. (English, short abstract in Japanese.)

Two localities, one a fine sand in the Koguti formation, the other a loose fine, lenticular sand in the impure Osawa limestone (Pliocene) have yielded a microfauna of 48 determined and listed Foraminifera. A single new species, Loxostoma etigoense Oinomikado, is described and figured.

Oinomikado, Tuneteru. Tertiary Foraminifera from the Amaze Oil Field: Geol. Soc. Japan, Jour., Vol. 47, No. 563, pp. 331-338, 1 text map, 1 text chart, Aug. 20, 1940. Paleon. Soc. Japan, Trans. No. 108, pp. 43-50, 1 text map, 1 text chart. (Japanese with an abstract in English.)

The paper is a report on the study of 8 foraminiferal samples from the Province of Niigati; 3 from the Haizume formation, one from the Nisiyama formation, 3 from the Siiya formation, and one from the Teradomari formation, all of them probably referable to the Mio-Pliocene series. The relative abundance of the species according to families is given and interpreted graphically.

Sugawara, Sho. A Consideration on the Stratigraphical Relation between the Mariana and Ponia Limestones on Rota Island, South Mariana Group. Jubilee Publ. in commemoration of Prof. Yabe's 60th Birthday, Vol. 2, pp. 734-741, 1940. (Japanese with English Abstract.)

Two limestones have been recognized on Rota Island of the South Mariana group. The first, a terrace-forming limestone referred to the Mariana, is a hard, massive locally porous rock built up of erect reef-building corals, Foraminifera and calcareous algae. The elevation of the highest and presumably the oldest terrace is 470 meters. They are interpreted as periodic uplifts during the Plio-Pleistocene period.

The second, the Ponia limestone, has much the same composition as the Mariana but the corals are fragmented. The beds are commonly thinly stratified and dip seaward at an angle of 20°. The maximum elevation of the Ponia does not exceed 200 meters. It is interpreted as a talus formed around the fringing reef of one of the higher terraces of the Mariana limestone.

Calcarina spengleri (Linnaeus) Baculogypsina sphaerulata (Parker and Jones) and Amphistegina radiata (Fichtel and Moll) occur abundantly in both the Mariana and Ponia limestones and are common along the coral reefs in the Recent seas of the same area. Cycloclypeus carpenteri Brady, abundant in the Ponia limestone but rare in the Mariana, is confined in the Recent seas to deeper water beyond the littoral zone.

Cinomikado, Tuneteru. Pliocene Foraminifera from the Koonzi Formation in the Takanabe Group, Miyazaki-ken: Geol. Soc. Japan, Jour., Vol. 48, No. 578, pp. 516-519, text figs. 1, 2a, 2b, November 20, 1941. Paleon. Soc. Japan, Trans., No. 127, pp. 96-99, text figs. 1, 2a, 2b. (English with a short abstract in Japanese.)

A road cut near Hagenosita, Kamie-mura, Koyu-gun, Miyazaki-ken, exposed the beds of the Koozni formation (Pliocene) from which the Foraminifera were collected. The silt in the lower part of the cut is overlain, with a slight unconformity, by alternating sand and silt, and the sand and silt is overlain by gravel. Lentils of Mollusca as well as Foraminifera are included in the silt. Judging from the foraminiferal assemblage, the silt may have been deposited in a moderately deep, open sea, and the overlying alternating sands and silt in shallow water. Fifty-three species are listed together with the zones in which they occur.

A single new species is described and figured, Lagena hyugaensis Cinomikado.

Syozi, Seiti. A Study on the Deep Sea Deposits collected from the South-western North Pacific by the H. M. S. Mansyu during the Years 1925-1928. Jubilee Publ. in commemoration of Prof. Yabe's 60th Birthday, Vol. 2, pp. 1217-1239, 1941. (Japanese with short English abstract.)

The article contains the description of the physical properties and the mineral and $CaCO_3$ contents of samples of the deep sea sediments collected by the Mansyu in 1925-1928.

Yabe, H. and Hatai, K. Additional Fossils from the Simaziri Beds of Okiniwa-zima, Ryukyu Islands, Japan. Japanese Jour. Geol. and Geog., Trans., Vol. 18, pp. 71-78, pl. 7, March, 1941. (English.)

Sixteen species from the Simaziri (Pliocene) beds are discussed and some of them figured. Haliotis is considered of significance ecologically because the distribution of the recent abalones is governed by the distribution of certain species of sea weed, their chief source of food. The vertical range of the sea weed is relatively small.

Wanzawa, Shoshino. Coral Reefs: The Science of the Ocean, Kaiyo no Kagaku, Vol. 2. No. 7, pp. 33-48, 11 text figures, July 1942.

The paper records observations on coral reefs in Saipan, Palau and Yap made in 1925; in the mandated islands in 1927-1928; observations and geological investigations especially of the limestones of the Marianas and Palau Islands in 1929; and observations on the coral reefs in the Marianas, the Carolines, the Marshalls, and an atoll in Ponal in 1940.

Coral reefs include fringing reefs, barrier reefs, atolls, and table reefs.

Reef flat: A kay is a strip of coral sand, the broken down residue of reef building organisms such as coral, calcareous algae and Foraminifera. The kay is commonly less than a kilometer wide but may be one hundred kilometers long and it rises about a meter above high water. A coral shingle rampart facing the open sea is characteristically developed along the shore; the inner slope toward the lagoon is gentle; but that toward the sea may be steep. Beach conglomerates and sandstones tend to form near the strand line. The reef flat extends from the strand line to the open sea and in southern Palau is several kilometers wide. Boulders from 30 to 40 centimeters in diameter are strewn over the inner zone of the flat to a distance of about 200 meters from the water's edge. The seaward margin of the flat is channeled at right angles to the shore line, and through these channels, the ocean streams in at high tide.

The foundation of the reef-flat and boulder zones is a limestone built up by reef-making coral. The seaward fringe abounds in coral growth and a prolific foraminiferal fauna inhabits the flat. The margin is commonly cliffed; the submarine cliff is toothed. The slope on the outside of a coral reef is commonly 45° and, when calculated to a depth of 200 meters, a dip of of 70° has been recorded. The same dip continues to 500-600 meters.

Toothed edges: The "toothed" edges of the outer margins of the reefs are common to the fringing and barrier reefs as well as of the atolls. Kuenen did not consider this feature the result of mechanical erosion as the sea water outside the coral reefs is so clear that it can contain little or no abrasive material; furthermore, the channel is of uniform width from its mouth to its head and the surface of the channel wall is smooth except where it is covered with living coral growth. Kuenen also maintained that the channels could not be due to solution because the sea water is already saturated with lime carbonate and, if it were not, the entire surface of the flat would be attached. In Funafuti atoll, coral boulders cover the flats between the channels and the spaces around the boulders are filled with foraminiferal sand. The corals flourish both along the sides of the channels and, on the flat divides, Lithothamnium and homoterma, as well as hexacorolla, alcyonaria, and Millepora, contribute to the reef.

The "toothed" edges may be cliffed at the open sea front or they may dip gently for a distance of about 100 meters. The cross channels are commonly 20 to 30 meters deep and, at low tide, extend about an equal distance in from the beach line.

The channels narrow toward the head and are commonly covered by reef-building corals which grow on either side and may continue to grow until they unite across the channel. In such channels, a blow hole is developed at the head. Masses of reef building coral also grow along the front of the flat between the channels and, in uniting, form a "toothed edge". Narrow depressions parallel to the channels may be seen on the older divides. Such depressions are the remnants of former channels which have been filled by foraminiferal sands as the reef flat grows outward. No living Foraminifera were observed on the divides between the channels of one of the Marshall atolls and no depressions indicating filled channels such as those on Palau were observed. In the Palau atolls the "toothed edge" is developed only on the outer seaward margin and not on the inner lagoonal margin. The author, Shoshino Hanzawa, agrees with Kuenen that the toothed edge is due to the outward growth of the coral reef and not to wave erosion.

Beach sandstones and Beach conglomerate or limestone are developed in an intertidal zone about 25 meters wide on the seaward side of the kays; the kay sandstone and kay conglomerate or limestone occur on the lagoonal side. The beach sandstones are laid down along the shore at a dip of about 10° and miniature cuestas may be formed by the succession of beds about 15 to 20 centimeters thick. The intertidal zone in which the sandstones and conglomerates are indurated is washed by the sea twice daily and is daily dried by the tropical sun. Lime carbonate is precipitated in the spaces around the sand grains, thus cementing them. David, Yonge, and Umbgrove attributed the cementation to the fresh water in the kay, but no evidence is presented indicating that the sands are more firmly cemented within the fresh water zone than they are elsewhere. Beach sandstones are fissured into square or polygonal blocks; beneath the sandstone is a loose sand, attacked by the waves at low tide. Notches are cut and the surface of the beach sandstone is broken down and fissured. The surface may be smooth or rough due to the action of the rains to which the sandstone is exposed at low tide.

Erosion by Waves in Reef-Flat: Observations on the reef-flat of an atoll of the Marshall islands indicates that the coral reef building goes on between

the beach conglomerate and the "toothed edges". The present atoll has developed according to Darwin from the fringing reef through the barrier reef because of the submergence of the base of the reef. According to Daly, the base did not sink, but the sea-level sunk 100 meters during the Pleistocene, then rose with the melting of the polar ice cap. For that reason, the base of the atoll was formerly 100 meters below the present sea-level and the reef-flat is not older than the Pleistocene.

The base of the reef flat may be contemporaneous with the Mariana limestone of the raised coral reef. The boring made on the atoll showed that the surficial sands and gravels continued with no apparent change in the fauna at least to the depth of 30 meters. The outer edge of the atoll is about two meters lower than its inner edge.

Beach line of Kay: The Kay is built up of broken remains of reef-building creatures brought in by wave action from the reef flats. The foraminiferal sands are washed up by waves from over the reef flats and not from the lagoon. Both ends of the kay bend toward the lagoon side. The beach sandstone and conglomerates usually parallel the coast but due to a change in direction of the currents they may be laid down oblique to the present shore line.

Negro Head: Boulders of coral limestone reaching two meters or more in diameter commonly occur on the surface of the reef flat. They are derived from a raised coral reef, thrown up by heavy waves commonly in the typhoon season, and come to rest as mushroom rocks on the reef flat. The Negro Heads are so called because they are overgrown with dark colored seaweed. All the Negro Heads examined by Hanzawa in the South Seas were derived from Recent reef building corals.

Rice-Field-like terraces: When limestone cliffs face the rough sea in tropical or sub-tropical regions, they are commonly skirted by intertidal terraces, rarely exceeding 10 meters in width, sloping gently seaward and partially drowned in standing pools of water like those of the rice fields. Isolated high terraces have also been observed. The bottoms of the pools are flat, as a rule, and covered by foraminiferal sands and a few small pieces of reef-building coral. Sea weeds grow on the floor of the pool and Foraminifera in the weeds. Such terraces are well developed in the Marianas and in Angaur of the Palau Islands. They do not develop in the islands inside the Palau barrier, nor around any of the volcanic islands, such as a large part of Palau proper, Yap and Tomier, Truk, Ponape and the Kusai Islands of the East Carolines. They do not occur in the Marshall Islands, but they do in Daitozima, 700 km. off the Loochoo Islands, in the Malaya Islands and in the Islands of the Indian Sea.

The calcareous sinter terraces of Mammoth Hot Springs in the Yellowstone National Park and the terraces in the terraces in the limestone cavein Syuhodo, Yamaguti Prefecture, Japan are similar in appearance to the terraces in the limestone islands of the South seas. It is recognized that the terraces at Mammoth Hot Springs are formed in the spring by calcareous algae but the origin of the structure is not understood. In river and sea shore terraces, the higher terraces are the older but in some, at least, of the terraces of Syuhodo the terraces are precipitates from underground streams and the altitude of the

terrace is not directly related to its age. The water fall at the terrace front is more swift in the central part of the fan than toward the edge where the surface of the limestone is a little higher. For that reason, precipitation is greater, the terrace is built up away from the center and at the same time is pushed outward.

Consign and Umbgrove analyzed the deposits at the bottom and edge of the terraces in the South Sea Islands and found them to be the same except for the higher magnesia content in the edge. This may be due to the solution of the floor of the pool by rain water, which is a better solvent than the sea water, which washes the edge.

Kuenen held that the edge does not grow upward, but Hanzawa does not agree with him. The edge is uniformly 15 to 20 centimeters above the floor of the pool, but its relation to sea level is variable. According to Erb, because the edge is made up chiefly of calcareous algae and the hard parts of other organisms, it is relatively resistent to erosion. The surf beats constantly upon the terraces and they are continually bathed in the waterfall. Food for algae and other organisms tends to be more abundant at the edge, thus stimulating the growth of the algae and other life in that area.

Solution of limestone by Sea Water: Limestone cliffs develop along the coasts of raised reefs such as Palau and the Mariana Islands. Notches cut by marine erosion occur not only along the base of the cliffs, but also at two or three higher levels, indicating the recent elevation of the reefs. The same phenomenon has been noted in the Malayas. Kuenen suggested that though the sea water in tropical regions is saturated with lime carbonate, the thin surficial layer of water would have the power of solution. In the Palau Islands, some of the sink holes have been filled with phosphate. After the extraction of the phosphate, it was found that the sea water entered through crevices and was affected by tidal movement and that the wall had been deeply cut horizontally by sea action. This was doubtless caused by the soluble action of sea water as mechanical action is inconceivable. Sea water may contain less lime carbonate at the surface directly after a storm, but this may have nothing to do with the solvent power of the sea water in the sink holes. The explanation of the cause of the horizontal cutting will depend on the future study of the character of tropical sea water.

Hanzawa, Shoshiro. Notes on Some Miocene Foraminifera from the Sagara Oil Field, Japan: Geol. Soc. Japan, Jour., Vol. 50, No. 595, pp. 243-253, pls. 4-8, April 20, 1943. Paleon. Soc. Japan, Trans., No. 165, pp. 125-135, pls. 7[4]-11 [8]. (English.)

Limestones containing Foraminifera were collected at seven localities in Totomi Province, Sizuoka Prefecture. The species from each locality are listed together with their abundance. In some exposures the Foraminifera were associated with calcareous algae, reef building corals, Mollusca, and Bryozoa. Five previously described Foraminifera are discussed at some length, and four of them are figured.

Kobayashi, Teiichi and Kimura, Toshi. A Study on the Radiolarian Rocks. Jour. Faculty of Science, Imperial Univ. Tokyo, Sec. 2, Vol. 7, part 2, pp. 75-173, 1944.

A comparison is made between the radiolarian rocks of Japan and those of other regions. The authors have undertaken a careful study of many Japanese radiolarian faunas from rocks of known age in order to determine the geologic ranges of species which make up these faunas. The European scheme of using the Cyrtoid percentage in radiolarian faunas as an indicator of age was found not so applicable in Japan. The percentage of living species also appears to be quite different in different regions. The Japanese radiolarian rocks were generally deposited in geosynclines which were subsequently shifted toward the oceanic side by orogenic movements.

Kobayashi, Teiichi and Yosida, Takasi. Odontosorites from North Manchuria. Japanese Jour. Geol. and Geog., Vol. 19, pp. 255-270, text figs. a-c, 1-8; text map; pl. 28, 1944. (English.)

Odontosorites is a coniopterid or tree fern. The leaves are found in an obscurely banded dacite or andesite, apparently of volcanic origin and laid down under water. The moderate undulation of the bands suggests a shallow water coastal deposit. Odontosoria s. l, possibly a collateral descendant, is a plant of the monsoon region more common in the warm temperate zone than in the tropics. In southwest Nippon it is distributed as far as the warm Kuroshio coastal current and is most flourishing in sunny lowlands and along the seashores. Although the prevailing temperature and humidity of Odontosorites time are speculative, the general climatic condition probably did not differ greatly from that of living Odontosoria. Odontosorites probably lived in the Middle and Upper Jurassic, doubtfully surviving into the early Cretaceous. During Middle and Upper Jurassic time the temperate and humid land of North Manchuria was covered with green vegetation in which ferns were particularly common. The so-called Ryokusin lake in which the plant remains were laid down may have been bordered by volcanic cones. The eruption of one of them possibly blew the tree fern in question to bits, and the leaves were so quickly buried and sealed in the falling ashes that they have escaped decomposition.

A bibliography of 42 items is included.

ECOLOGY OF MARINE INVERTEBRATE FAUNA OF THE PACIFIC

by

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The annotated bibliography that follows is an attempt to bring together the principal titles of works on marine invertebrate faunas of the Pacific region that may have some bearing, directly or indirectly, on paleontology. I am fully aware of the incompleteness of the list. It would require a long time to assemble all of the worthy contributions that have been made during the past century in this great area.

The Japanese, Micronesian, Asiatic, and Australian near-shore areas have been omitted in anticipation that they will be covered by others. The Pacific coast of the Americas is included, inadequately, but the works cited and the bibliographies they contain may serve as a basis for a more complete survey of a particular subject. Geological titles are omitted, for the most part, except those which seem to have some direct relation to paleoecology.

Agassiz, A., The coral reefs of the Hawaiian Islands, Mus. Comp. Zool., Harvard, Bull. vol. 17, no. 3, pp. 121-170, 1889.

Personal observations of the author were confined to reefs of the islands of Oahu, Maui, and Hawaii. No evidence of any considerable elevation of the islands was observed, nor did the author see evidence of any special subsidence. Subsidence of about 50 feet was recognized at Kalapana, Hawaii.

Agassiz, A., Coral reefs of the tropical Pacific, Mus. Comp. Zool., Harvard, Mem., vol. 28, pp. 1-410, 1903.

Observations on islands and coral reefs from the Marquesas to the Marshall Islands during the expedition of the Albatross from August 1889 to March 1900.

Allan Hancock Pacific Expeditions. Six major cruises since 1931, in which the coast lines of Mexico, Central America, northern South America and the Galapagos Islands were explored. Scientific results relating to marine invertebrate fauna issued as follows: Vol. 2, Mollusks, A. M. Strong and L. G. Hertlein; Nemerteans, W. R. Coe; Sea urchin, H. L. Clark: Vol. 4, Hydroids, C. M. Fraser: Vol. 5, Crustaceans, J. S. Garth, S. A. Glassell, W. L. Schmitt; Pycnogonids, W. A. Hilton: Vol. 6, Foraminifera, J. A. Cushman and I. McCulloch, C. G. Lalicker and I. McCulloch: Vol. 7, Polychaetous Annelids, O. Hartman, (also in Report No. 3, 1944): Vol. 8, Brittle stars, A. Hill; Holothurians, E. Deichmann; Sea stars, F. Ziesenhenne: Vol. 10, Polychaetous Annelids, O. Hartman: Vol. 11, Sponges, M. G. Dickinson.

Bagg, R. M., Jr., Foraminifera collected near the Hawaiian Islands by the steamer Albatross in 1902, Proc. U. S. Nat. Mus. vol. 34, no. 1603, pp. 113-168, 1908.

More than 200 species from 19 stations are recorded. Depth records are from 104 to 1544 fathoms. Few deep water species were found below 1000 fathoms. The greatest variety of forms were from 865 fathoms.

Barrows, A. L., An unusual extension of the distribution of the shipworm in San Francisco Bay, California, Univ. of Calif. Pub. Zool., vol. 18, pp. 27-43, 1917.

The activity of Teredo diegensis is related to salinity. Salinity of at least 10 parts per 1000 seems to be required for its existence. Salinity of 13 to 14 parts per 1000 greatly increases its activity.

Berry, S. S., The cephalopods of the Hawaiian Islands, U. S. Bur. Fisheries, Bull., vol. 32, pp. 255-362, 1912.

A report on specimens collected by the Albatross in 1902, with a few from other sources. No examples of Loligo or Sepia were taken. Ocean currents may restrict the distribution of these forms.

Bigelow, R. P., Stomatopoda of the southern and eastern Pacific Ocean and the Hawaiian Islands, Mus. Comp. Zool., Harvard, Bull., vol. 72, no. 4, pp. 105-191, 1931.

The article lists 17 species and varieties taken by the Albatross from August 1899 to March 1900, and from October 1904 to March 1905. One new species, Souilla mauiana, was taken in 28-43 fathoms between Maui and Lanai Islands, Hawaii.

Böhm, A., Distribution and variability of Ceratium in the northern and western Pacific, B. P. Bishop Mus., Bull. 87, pp. 1-46, 1931.

Böhm, A., Dinoflagellates of the coastal waters of the western Pacific, B. P. Bishop Mus., Bull. 137, pp. 1-54, 1936.

These two articles record dinoflagellates from the plankton about Hawaii and in the western Pacific. The variability of Ceratium is correlated with environment. Three distributional areas were recognized between Singapore and Shanghai during the southeast monsoon.

Boone, L., The littoral crustacean fauna of the Galapagos Islands, Part I. - Brachyura, Zoologica, vol. 8, no. 4, pp. 127-288, 1931.

Boone, L., The littoral crustacean fauna of the Galapagos Islands, Part II. - Anomura, Zoologica, vol. 14, no. 1, pp. 1-62, 1932.

These two articles record crustaceans collected by the Arcturus Oceanographic Expedition. Species taken from the shore to 100 fathoms are recorded. Species taken below 100 fathoms show affinities with typical deep water forms.

Boschma, H., The Fungidae (Anthozoa) collected by Mr. Cyril Crossland at Tahiti and neighboring islands, Proc. Z. S. L., 1929, pp. 43-47.

In this article the author calls attention to the lack of clear cut distinctions between species.

Boschma, H., Papers from Dr. Th. Mortensen's Pacific Expedition 1914-1916. XXVIII. Madreporaria 1. Fungidae, Vidensk. Medd. fra Dansk Naturh. Foren., Bd. 79, pp. 185, 259, 1925.

Material from the Danish Expedition to the Kei Islands 1922, and from other localities, is included. The geographical distribution of species is given consideration.

Bryan, W. A., A monograph of Marcus Island, B. P. Bishop Mus., Occ. Papers, vol. 2, no. 1, pp. 77-139, 1903.

The physical features of the island as noted during a visit in 1902 are described. A survey of land and marine plant and animal life was made and the results recorded.

Burkenroad, M. D., Sergestidae (Crustacea Decapoda) from the Lower California Region, with descriptions of two new species and some remarks on the organ of Pesta in Sergestes, Zoologica, vol. 22, pt. 4, no. 25, pp. 315-329, 1937.

Six species are recorded with two described as new. A list of sergestids known from the Pacific is included.

Burkenroad, M. D., Peneidae from the region of Lower California and Clarion Island, with descriptions of four new species, Zoologica, vol. 23, pp. 55-91, 1938.

The material was collected by the Templeton Crocker Expedition of the New York Zoological Society, 1936. Deep water peneids of the Pacific are not so closely related to those of the Atlantic as they are to fauna of other regions.

California Academy of Sciences. Results of various expeditions issued in numbers of the Proceedings.

1. Expeditions of the California Academy of Sciences to the Gulf of California, 1921, 1922, and 1925.

2. The Templeton Crocker Expedition to the Galapagos Islands, 1932.

Vol. 13, Crustacea, M. J. Rathbun; W. L. Schmitt, Opisthobranchiate Mollusca, F. M. MacFarland, Whale barnacles, I. E. Cornwall,

Vols. 15, 16, 17, 19, 21, 23, Articles on marine mollusks by F. Baker, G. D. Hanna, L. G. Hertlein and A. M. Strong.

Cary, L. R., Studies on the coral reefs of Tutuila, American Samoa, with reference to the Alcyonaria, Carnegie Inst. of Wash., Pub. No. 413, pp. 53-98, 1931.

The distribution of Alcyonaria is determined by their capacity to adjust themselves to conditions on the reef. Alcyonarian spicule rock was found at 83 out of 94 stations. The author considers Alcyonaria very important reef builders.

Challenger Expedition, 1873-1876. Reports published, 1881-1895. Thirty-two volumes devoted to zoology. Many articles and monographs treating (in part) of marine fauna of the Pacific.

Chamberlin, R. T., The geological interpretation of the coral reefs of Tutuila, American Samoa, Carnegie Inst. Pub. No. 340, pp. 147-178, 1924.

Clark, H. L., The echinoderms of Peru, Mus. Comp. Zool., Harvard, Bull. 52, pp. 319-353, 1910.

The area is not rich in echinoderms. Starfishes are more abundant than other groups. Two faunas meet on the coast of Peru, one from Chili, the other from Panama.

Clark, H. L., North Pacific ophiurans, U. S. Nat. Mus., Bull. 75, 1911.

Deep water species generally are widely distributed forms. The discovery of species common with North Atlantic ones confirms the author's belief in a circumpolar fauna.

Clark, H. L., Eastern tropical Pacific Asteroidea, Mus. Comp. Zool., Harvard, Mem. vol. 39, no. 3, pp. 71-113, 1920.

Collections made by the Albatross from October 1904 to March 1905 are recorded. Both littoral and deep water forms are included.

Clark, H. L., Notes on echinoderms from the west coast of Central America Zoologica, vol. 25, no. 22, pp. 331, 352, 1940.

This article records 57 species collected by the Zaca in 1937-38. Most of the species are common, well known forms. Four new species and two new varieties are described. Geographic and bathymetric distributions are given.

Clarke, S. F., The Hydroids, Mus. Comp. Zool., Harvard, Bull. vol. 25, no. 6, pp. 71-77, 1894.

The material was collected by the Albatross during 1891 from the west coast of Central America to the Galapagos Islands and in the Gulf of California. Depth records range from 66 to 1168 fathoms.

Crane, J., Brachygnathous crabs from the Gulf of California and the west coast of Lower California, Zoologica, vol. 22, pp. 47-78, 1937.

Crane, J., Oxystomatous and Dromiaceous crabs from the Gulf of California and the west coast of Lower California, Zoologica, vol. 22, pt. 2, no. 7, pp. 97-108, 1937.

These two articles record crustaceans collected by the Templeton Crocker Expedition of the New York Zoological Society 1936. Observations on food, color, and habits of the species are included. Geographic and bathymetric ranges are given.

Crickmay, G. W., Ladd, H. S., and Hoffmeister, J. E., Shallow-water globigerina sediments, Bull. Geol. Soc. Amer., vol. 52, pp. 79-106, 1941.

The conditions under which Globigerina limestones and related deposits may accumulate are discussed.

Crossland, C., Notes on the ecology of the reef-builders of Tahiti, Proc. Z. S. L., 1928 (2), pp. 717-734.

Crossland, C., Coral reefs of Tahiti, Moorea and Rarotonga, Linn. Soc. Zool., Journ. vol. 36, pp. 577-620, 1928.

Crossland, C., The reduced building-power and other variation in the astrean corals of Tahiti, with a note on Herpetlitha limax and Fungia spp., Proc. Z. S. L., 1932 (2), pp. 351-392.

Crossland, C., Coral faunas of the Red Sea and Tahiti, Proc. Z. S. L., 1935 (3), pp. 499-504.

Crossland, C., Further notes on the Tahitian barrier reef and lagoons, Linn. Soc. Zool., Journ. vol. 40, pp. 459-474, 1939.

In these five articles are recorded first-hand observations on the reefs of Tahiti, their formation and character. The paucity of certain corals in Tahiti and their reduced building power is attributed to ecological causes rather than wholly to geographical isolation. Structural disorganization in many of the corals is seen. Annular cracking of a continuous reef is suggested as the origin of lagoons. The belief is expressed that Moorea is from four to six times as old as Tahiti, and Raratonga is believed to be older than Moorea. Lithothamnionaceae are considered of minor importance in reef building in Tahiti. The effect of the flood of January 1926 on the fauna and flora of lagoon reefs is discussed.

Cruise of the Carnegie during 1928-1929. Carnegie Inst. of Wash. Publications - Results relating to Biology:

Biology I. Copepods, Pub. 536, C. B. Wilson: Biology II. Ocean Tintinnoina, Pub. 537, A. S. Campbell: Biology III. Peridineales, Pub. 542, H. W. Graham: Biology IV. Numerous papers on invertebrates and vertebrates, Pub. 555, Collaboraters: Biology V. The genus Ceratium, Pub. 565, H. W. Graham and N. Bronikovsky. (Various articles deal in part with Pacific areas).

Cushman, J. A., A monograph of the Foraminifera of the North Pacific Ocean, U. S. Nat. Mus., Bull. 71, parts 1-6, 1910.

The factors in the distribution of Foraminifera are depth, temperature and currents. Three chief faunas were noted: coral reef fauna; fauna off the coast of Central America and Mexico, and the fauna between the Philippine Islands and Japan.

Cushman, J. A., Foraminifera from Murray Island, Australia, Papers from Marine Biol., Carnegie Inst. of Wash., vol. 9, pp. 289-290, 1918.

Five lots collected by A. G. Mayor from shoal water form the basis of this article. Forty-three species are listed.

Cushman, J. A., Samoan Foraminifera, Papers from Marine Biol., Carnegie Inst. of Wash., vol. 21, pp. 1-75, 1924.

Species are recorded from nine stations, depths ranging from 12 to 50 fathoms. Species were more abundant at 50 fathoms. The author is convinced that shallow water Foraminifera are as limited in distribution as many other groups of organisms.

Cushman, J. A., Foraminifera, in marine zoology of tropical central Pacific, B. P. Bishop Mus., Bull. 27, pp. 121-144, 1925.

The article records nearly 100 species taken by the Tanager Expedition in the vicinity of the leeward islands of the Hawaiian group, and Johnston Island. Samples were from the shore to 200 fathoms.

Dall, W. H., The Mollusca and brachiopods, Mus. Comp. Zool., Harvard, Bull. vol. 43, no. 6, pp. 203-487, 1908.

The deep water fauna west of Panama is compared with that of the Antillean area. The belief is expressed that the land connection between the Atlantic and the Pacific is very ancient.

Dall, W. H., Summary of the mollusks of the family Alectrionidae of the west coast of America, U. S. Nat. Mus., Proc., vol. 51, pp. 575-579, 1917.

The article lists nearly 50 species, many of which are new. Bathymetric records are given.

Dall, W. H., Bartsch, P., and Rehder, H. F., A manual of the recent and fossil marine mollusks of the Hawaiian Islands, B. P. Bishop Mus., Bull. 153, pp. 1-233, 1938.

This paper is a systematic treatise on the Pelecypoda of Hawaii. The authors favor the drift theory to account for the presence of littoral mollusks about the Hawaiian Islands.

Daly, R. A., The glacial-control theory of coral reefs, Proc. American Acad. Arts. and Sci., vol. 51, pp. 155-251, 1915.

Davis, W. M., The coral reef problem, Spl. Pub. No. 9, American Geographical Society, pp. 1-596, 1928.

This volume includes a great deal of information on coral reefs and a remarkably complete bibliography of the voluminous literature on reefs.

Deichmann, E., Holothurians from the Gulf of California, and the west coast of Lower California and Clarion Island, Zoologica, vol. 23, pt. 2, no. 10, pp. 161-176, 1937.

A report on collections of the Templeton Crocker Expedition of the New York Zoological Society, 1936. Fourteen species are listed, with the known ranges of several extended. Bathymetric distribution of the species is given.

Edmondson, C. H., Crustacea from Palmyra and Fanning Islands, B. P. Bishop Mus., Bull. 5, pp. 1-43, 1923.

The fauna of these islands clearly shows the influence of migrations from the south Pacific. There is a similarity of the fauna to that of Hawaii, but the islands (Palmyra and Fanning) appear to be the northern distributional limit of certain Indo-Pacific forms.

Edmondson, C. H., Crustacea, in marine zoology of tropical central Pacific, B. P. Bishop Mus., Bull. 27, pp. 1-62, 1925.

The survey covered by this article includes Johnston and Wake Islands and the leeward islands of the Hawaiian group. About 90 percent of the marine crustaceans of Johnston Island are identical with those of Hawaii. About 75 percent of the species at Wake Island are also found in Hawaii.

Edmondson, C. H., Ecology of an Hawaiian coral reef, B. P. Bishop Mus., Bull. 45, pp. 1-64, 1928.

Results of altered physical and chemical conditions on Hawaiian corals are recorded. Species of Fungia, Favia, Leptastrea and Psammocora are among the more resistant to altered conditions.

Edmondson, C. H., Growth of Hawaiian corals, B. P. Bishop Mus., Bull. 58, pp. 1-38, 1929.

Shallow water corals in Hawaii grow less rapidly than related species in the south Pacific or Indian Oceans. The rate of growth in Hawaii compares favorably with that recorded for corals in the Bahamas and at the Dry Tortugas.

Edmondson, C. H., Teredinidae of Hawaii, B. P. Bishop Mus., Occ. Papers, vol. 17, no. 10, pp. 97-150, 1942.

Fifteen species are recorded as active about Hawaii. Six of these are listed as new. Bankia is now established in Hawaiian waters. An internal parasitic copepod infesting shipworms is reported.

Edmondson, C. H., Callianassidae of the central Pacific, B. P. Bishop Mus., Occ. Papers, vol. 18, no. 2, pp. 35-61, 1944.

A small collection is recorded from Hawaii, with species from Guam, Wake Island, and Tahiti. Five species from Hawaii are listed as new.

Etheridge, R., and collaborators, Lord Howe Island, its zoology, geology, and physical characters, Australian Mus., Mem., no. 2, pp. 1-132, 1889.

The article is a report of a survey of the island made in August-September, 1887. A general account of land and marine fauna is included.

Faustino, L. A., Coral reefs of the Philippine Islands, Philippine Journ. Sci., vol. 44, no. 3, pp. 291-307, 1931.

Ecological factors as depth, temperature, currents, salinity, etc. have determined the location of reefs rather than any land area. Tertiary

and Pleistocene coral reefs are widely scattered in the Philippines.

Faxon, W., The Crustacea, Mus. Comp. Zool., Harvard, Mem. vol. 18, pp. 1-292, 1895.

The stalk-eyed crustaceans described were collected by the Albatross during 1891 on the west coast of Central and South America and off the Galapagos Islands. Temperature is believed to be the chief factor in the distribution of crustaceans. Littoral species of temperature zones are found in deep water near the equator.

Fisher, W. K., Starfishes of the Hawaiian Islands, U. S. Fish Comm., Bull. for 1903, vol. 23, pt. 3, pp. 987-1130, 1906.

Species collected by the Albatross in 1902 are listed. Specimens were taken from the shore to depths of about 1000 fathoms. The fauna is closely related to the south Pacific and Indian Ocean forms. Few affinities with the west American species were seen.

Fisher, W. K., The holothurians of the Hawaiian Islands, U. S. Nat. Mus., Proc., vol. 32, pp. 637-744, 1907.

The article records 46 species collected by the Albatross during 1902. The reef and shore forms are typically tropical.

Fisher, W. K., Sea stars from Arcturus Oceanographic Expedition, Zoologica, vol. 8, no. 9, pp. 487-493, 1928.

The article describes 18 species mostly from deep water. All were previously known. One species, Mithrodia bradleyi, is known from Lower California and Hawaii.

Fraser, C. M., Some hydroids of the Vancouver Island region and notes on some Alaskan hydroids, Roy. Soc. of Canada, Trans., Third Ser., vol. 8, pp. 99-222, 1914.

All species known from Puget Sound northward to the Queen Charlotte Islands are described and figured. The geographical distribution of species is given. Material was from the shore to depths of 30 to 35 fathoms.

Galtsoff, P. S., Pearl and Hermes Reef, Hawaii, Hydrographical and Biological Observations, B. P. Bishop Mus., Bull. 107, pp. 1-49, 1933.

Results of a survey of the pearl oyster beds in 1930 are recorded. The oyster population was found to have reached a dangerous low limit.

Gardiner, J. S., On the perforate corals collected by the author in the south Pacific, Proc. Z. S. L., 1898, pp. 257-276.

Gardiner, J. S., On the fungoid corals, Proc. Z. S. L., 1898, pp. 252-538.

Gardiner, J. S., On the turbinoid and oculinoid corals, Proc. Z. S. L., 1898, pp. 994-1000.

Gardiner, J. S., On the Astrean corals collected by the author in the south Pacific, Proc. Z. S. L., 1899, pp. 734-764.

In these four articles corals from Funafuti, Rotuma, and Fiji are described. Both shoal water and dredged species are included.

Göes, A., The Foraminifera, Mus. Comp. Zool., Harvard, Bull., vol. 29, no. 1, pp. 1-103, 1896.

A report on dredged material from the area between the west coast of Central America and the Galapagos Islands, taken by the Albatross in 1891. A decrease in foraminiferal fauna is seen below 1200 fathoms. At depths from 1000 to 1400 fathoms species are nearly common for Pacific and Caribbean areas.

Hansen, H. J., The Isopoda, Mus. Comp. Zool., Harvard, Bull., vol. 31, no. 5, pp. 93-129, 1897.

Results of a collection taken by the Albatross during 1891, between Panama and Japan. Fourteen deep water species are described as new. One well known terrestrial form is included.

Hedgpeth, J. W., A new Pycnogonid from Pescadero, Calif., and distributional notes on other species, Wash. Acad. Sci., Journ. vol. 30, no. 2, pp. 84-87, 1940.

A littoral form collected on a pebble beach from eelgrass holdfasts.

Hedgpeth, J. W., On a species of pycnogonid from the North Pacific, Wash. Acad. Sci., Journ., vol. 33, no. 7, pp. 223-224, 1943.

The single species discussed in this article was taken by the Albatross in 1890 off the northwestern United States at 786 fathoms. Paratypes were taken at 1,569 fathoms.

Hedley, C., and collaborators, The atoll of Funafuti, its zoology, botany, ethnology, and general structure, Australian Museum Mem. III, pp. 1-609, 1896-1900.

The physical features, geology, vegetation, climate, etc., are described, with accounts by the several authors of land and marine animals collected.

Hertlein, L. G., and Strong, A. M., Mollusks from the west coast of Mexico and Central America, Part I, Zollogica, vol. 25, no. 25, pp. 369-430, 1940.

Hertlein, L. G., and Strong, A. M., Mollusks from the west coast of Mexico and Central America. Part II, Zoologica, vol. 28, no. 19, pp. 149-167, 1943.

These two articles report collections from the Templeton Crocker Expedition of 1936, and the Eastern Pacific Zaca Expedition of 1937-38. Most of the material was dredged from depths less than 100 fathoms. The range of several known species was extended.

Hickson, S. J., Notes on the collection of specimens of the genus Millepora obtained by Mr. Stanley Gardiner at Funafuti and Rotuma, Proc. Z. S. L., 1898, pp. 828-833.

But one species of the genus Millepora is recognized. The term "Facies" is used to denote various forms of growth.

Hickson, S. J., The Stolonifera and Alcyonacea collected by Dr. Willey in New Britain, etc., Zoological Results, pt. 4, pp. 493-508, 1900.

Two species of Stolonifera and 20 of Alcyonacea are recognized. Distributional records are given.

Hilton, W. A., Pycnogonids from Hawaii, B. P. Bishop Mus., Occ. Papers, vol. 27, no. 3, pp. 43-55, 1942.

An article reporting on a collection of littoral forms from Hawaii. Eight new species, one new variety and an immature specimen are described.

Hoffmeister, J. E., Some corals from American Samoa and the Fiji Islands, Papers from the Dept. of Marine Biol., Carnegie Inst. of Washington, vol. 22, pp. 1-84, 1925.

Massive growth forms of corals reach greater development near the outer edge of the reef. Corals with stout branches begin near the center of the reef and increase toward the outer edge. Fragile forms grow best in the center of the reef. The larger number of corals grows in comparatively quiet water.

Hoffmeister, J. E., Some corals from Tahiti, Wash. Acad. Sci., Journ. vol. 19, pp. 357-365, 1929.

In this article the author describes 24 species of shallow water corals from Tahiti. Most of them are common in Oceania and surrounding areas. One species is described as new.

Hoffmeister, J. E., Ladd, H. S., and Alling, H. L., Falcon Island, Amer. Jour. Sci. 5th Ser., vol. 18, pp. 461-471, 1929.

The authors describe an active Tongan volcano built of pyroclastic materials, suggesting that many southwest Pacific islands may be built on pyroclastic foundations.

Hoffmeister, J. E., and collaborators, Geology of Eua, Tonga, B. P. Bishop Mus., Bull. 96, pp. 1-96, 1932.

The article reports on the physiography and geology of the island, with a systematic account of the corals of the elevated limestones. The older rocks of the island are early Eocene or pre-Eocene. Sections on petrography by H. L. Alling, and on Foraminifera by G. L. Whipple are included.

Howe, M. A., Calcareous algae from Murray Island, Australia, and Cocos-Keeling Islands, Papers from Dept. of Marine Biol., Carnegie Inst. of Wash., vol. 9, pp. 291-296, 1918.

Seven species of reef-producing calcareous algae were recognized in material from Murray Island and three from Cocos-Keeling Islands.

Hult, J., Crustacea Decapoda from the Galapagos Islands collected by Mr. Rolf Blomberg, Arkiv. f. Zoologi, Band 30, A, no. 5, pp. 1-18, 1938.

In a small collection of littoral and fresh water forms the author found species exclusively Pacific, and also those ranging in the Atlantic as well as in the Pacific.

Kelsey, F. W., Mollusks and brachiopods collected in San Diego, California, San Diego Soc. Nat. Hist., Trans., vol. 1, no. 2, pp. 31-55, 1905.

The article includes a complete list of species known at San Diego, within a coast line limit of 25 miles. Few species beyond a depth of 200 fathoms are included.

Kofoid, C. A. and Adamson, A. M., The Dinoflagellata: the family Heterodinidae of the Peridinioidae, Mus. Comp. Zool., Harvard, Mem., vol. 54, no. 1, pp. 1-136, 1933.

The article is a report on the collections of the Albatross taken from October 1904 to March 1905. Material was taken mainly at depths of about 300 fathoms. Thirty-five species are recorded, five of which are new, as is also one genus.

Ladd, H. S., and collaborators, Geology of Vitilevu, Fiji, B. P. Bishop Mus., Bull. 119, pp. 1-263, 1934.

Includes brief descriptions of modern reefs and a discussion of paleoecology.

Ladd, H. S., Hoffmeister, J. E., and collaborators, Geology of Lau, Fiji, B. P. Bishop Mus., Bull, 181, pp. 1-399, 1945.

Includes description of existing reef and discussion of paleoecology.

Ludwig, H., The Holothurians, Mus. Comp. Zool., Harvard, Mem., vol. 17, no. 3, pp. 1-183, 1894.

This is a report on collections made by the Albatross in 1891. Forty-six species are recognized. Depth records of the species are given.

Lutken, C. F. and Mortensen, Th., The Ophiuroidea, Mus. Comp. Zool., Harvard, Mem., vol. 23, no. 2, pp. 93-208, 1889.

Collections were taken by the Albatross during 1891. Sixty-six species are listed; 53 being new. Depth records are given.

Marshall, P., Geology of Mangaia, B. P. Bishop Mus., Bull. 36, 1927.

Includes brief description of existing reef and discussion of formation of elevated limestone.

Mayor, A. G., Ecology of the Murray Island coral reef, Papers from Dept. of Marine Biol., Carnegie Inst. of Wash., vol. 9, pp. 1-48, 1918.

The physical features of the reef with special reference to corals are discussed. Experiments on the ability of corals to resist high temperature, silt, drying, etc., were made. Corals grow best in clear cool water where the range of temperature is slight. Solubility of limestone in sea water is negligible.

Mayor, A. G., Structure and ecology of Samoan reefs, Papers from Dept. of Marine Biol., Carnegie Inst. of Wash., vol. 19, pp. 1-25, 1924.

Samoan reefs are compared with that of Murray Island. The optimum location of species of corals on the reef in Pago Pago Harbor was determined. The effect of high temperature on corals was noted, and also the effect of heavy rains and muddy water.

Mayor, A. G., Growth rate of Samoan corals, Papers from Dept. of Marine Biol., Carnegie Inst. of Wash., vol. 19, pp. 51-72, 1924.

The growth rate of corals in Samoa is greater than in the Atlantic where records have been made. It is estimated in the article that coral growth in Samoa is equivalent to a layer of coral 8 mm. thick added to the reef annually.

Mayor, A. G., Rose atoll, American Samoa, Papers from Dept. of Marine Biol., Carnegie Inst. of Wash., vol. 19, pp. 73-91, 1924.

The article describes the physical character of the atoll. Observations on the atoll rim and the prevailing forms of marine life found on it are recorded. Evidence points to a lowering of sea level rather than an elevation of the atoll.

Mortensen's Pacific Expedition 1914-16 (Dr. Th. Mortensen's Pacific Expedition 1914-16). Vidensk. Meddel. f. Dansk Naturh, - Numerous articles by various authors on groups of invertebrates, including Actiniaria, Bryozoa, Cirrepedia, Crustacea, Echinodermata, Mollusca, Sponges, etc. Articles issued in numbered series in volumes ranging from Vol. 69, 1918, to date.

Nutting, C. C., Report on the Hydroida collected by the United States Fisheries Steamer "Albatross" in the Philippine region, 1907-1910, U. S. Nat. Mus., Bull. 100, vol. 6, pt. 3, pp. 195-242, 1927.

Most of the material was collected at less than 200 fathoms. The area is not especially rich in hydroids.

Oldroyd, I. S., The marine shells of the west coast of North America. Stanford Univ. Pub., University Series, Geolog. Sciences, vol. 1, no. 1, 1924: vol. 2, pt. 1 - pt. 3, 1927.

A report on the marine shells from the Arctic Ocean to San Diego, California. Geographical and geological ranges are given.

Ostergaard, J. M., Fossil marine mollusks of Oahu, B. P. Bishop Mus., Bull. 51, pp. 1-32, 1928.

Most of the 82 species of fossil mollusks recorded from the raised reefs of Oahu are now living in the shoal water about the island. Three species are believed to be universally extinct, and 8 species now fossil in Oahu are reported to be living elsewhere. On the basis of extinct forms the author believes the emergent limestones of Oahu are not older than Pleistocene.

Ostergaard, J. M., Recent and fossil marine mollusks of Tongatabu, B. P. Bishop Mus., Bull. 131, pp. 1-59, 1935.

Of the 38 species reported as fossils in the limestones of Tongatabu none is extinct. All are living in surrounding waters or elsewhere. The belief is expressed that the limestones of Tongatabu are late Pleistocene.

Ostergaard, J. M., Reports on fossil Mollusca of Molokai and Maui, B. P. Bishop Mus., Occ. Papers, vol. 15, no. 6, pp. 67-77, 1939.

Uniformity of species of fossils from the lowest to the highest horizons indicate deposits of nearly the same age. There are indications of a rapid change in relation of sea and land. Three species of mollusks unknown to Hawaii were found in raised deposits.

Packard, E. L., Molluscan fauna from San Francisco Bay, Univ. Calif. Pub. Zool., vol. 14, no. 2, pp. 199-452, 1918.

Collections made by the Albatross yielded 81 species and varieties. Environmental factors affecting molluscan fauna within the bay are discussed. The fauna of the bay is compared with that outside the bay in the ocean. Species of the bay are, for the most part, northward ranging.

Pollock, J. B., Fringing and fossil coral reefs of Oahu, B. P. Bishop Mus., Bull. 55, pp. 1-56, 1928.

In this article the belief is expressed that coralline algae have contributed more to the reefs of Oahu than have corals. It is suggested that Foraminifera may have played an important role in the development of reefs of the island. No evidence to support the subsidence theory was seen in the reefs about Oahu.

Rathbun, M. J., The Brachyura and Macrura of the Hawaiian Islands, U. S. Fish Comm., Bull. for 1903, vol. 23, pt. 3, pp. 827-930, 1906.

The known species in Hawaiian waters are increased in number to 314. The fauna is almost entirely Indo-Pacific. Some deep water forms are cosmopolitan. Little affinity with American fauna is seen.

Schmitt, W. L., The marine Decapod Crustacea of California, Univ. Calif. Pub. Zool., vol. 23, pp. 1-359, 1921.

This report is based on collections made by the Albatross in San Francisco Bay, together with material from the littoral or continental shelf zones. A few deep sea forms are included. The geographical and bathymetrical distribution of species is recorded.

Setchell, W. A., A botanical view of coral reefs, especially of those of the Indo-Pacific Region, Third Pacific Sci. Cong., Tokyo, vol. 2, pp. 1837-1843, 1926.

The author of this article believes that nullipores are the controlling organisms in reef-formation in the central Pacific. The three types of reefs result from three types of nullipores. The depth limit of 180 feet for reefs is unnecessary.

Setchell, W. A., Nullipore versus coral in reef formation, Proc. Amer. Phil. Soc., vol. 65, pp. 136-140, 1926.

In this article the opinion is expressed that nullipores are the most important components of reefs; that without them no reefs could be formed.

Sivickis, P. B., New Philippine shipworms, Philip. Journ. Sci., vol. 37, pp. 285-298, 1928.

The author includes 16 species, 15 of which are described as new. All are shoal water forms.

Stevens, B. A., Hermit crabs of Friday Harbor, Washington, Pub. Puget Sound Biol. Station, vol. 3, pp. 273-309, 1921.

Thirteen species are listed in this article. General, local, and bathymetric distributions are given.

Strong, A. M. and Howe, H. N., West American species of the genus Phos, San Diego Soc. Nat. Hist., Trans., vol. 8, no. 22, pp. 307-316, 1936.

The eight known species from the west American coast are reported in this article. Depth records are given.

United States Exploring Expedition, Land and marine explorations in the Pacific (in part) from 1838 to 1842.

Special attention is called to Vol. 7, Zoophytes, by J. D. Dana, pp. 1-740, 1846; Vol. 12, Mollusca and Shells, by A. A. Gould, pp. 1-510, 1852; Vols. 13 and 14, Crustacea, by J. D. Dana, pp. 1-685, 1852 and pp. 686-1618, 1853. (Plates of Vols. 13 and 14 issued in 1855).

Vaughan, T. W., Recent Madreporaria of the Hawaiian Islands and Laysan, U. S. Nat. Mus., Bull. 59, 1907.

A systematic account of all corals known to exist in the Hawaiian area. Mostly collected by the Albatross in 1902, a few from other sources. The physical conditions under which the species live, their bathymetric distribution, and their affinities with corals of other Indo-Pacific regions are set forth. It is suggested that the absence of some corals from Hawaiian waters may be due to their larvae being unable to be transported long distances.

Vaughan, T. W., Shoal water corals from Murray Island, Cocos-Keeling and Fanning Island, Carnegie Inst. of Wash., vol. 9, pp. 49-219, 1918.

A systematic report on corals collected at Murray Island by A. G. Mayor, at Cocos-Keeling Islands by F. Wood Jones, and at Fanning Island by Carl Elschner. The geographic distribution of the species is included, and also a list of corals from the Kermadec Islands.

Vaughan, T. W., Corals and coral reefs of the Pacific, Proc. Fifth Pacific Sci. Cong., Canada, vol. 1, Append. 1, pp. 343-360, 1933.

This article is a classified list (122 titles) of literature contributing toward our knowledge of coral reefs. Some reports are quoted in part.

Verrill, A. E., Monograph of the shallow-water starfishes of the North Pacific coast from the Arctic Ocean to California, Smithsonian Inst. Pub. 2140, pp. 1-408, 1914.

This article reports on material collected chiefly by the Harriman Expedition. The northwestern coast of North America is the metropolis of shallow-water starfishes. No other known region is so rich in species and individuals. Both shoal water and deep water species are abundant.

Way, E., Brachyura and crab-like Anomura of Friday Harbor, Washington, Pub. Puget Sound Biol. Station, vol. 1, pp. 349-382, 1917.

Twenty-eight species are listed from littoral and dredged material.

Wentworth, C. K., and Ladd, H. S., Pacific Island Sediments, Univ. of Iowa Studies in Natural History, vol. 13, pp. 1-47, 1931.

The authors describe many island sediments including unusual types of organic origin.

Weymouth, F. W., Synopsis of the true crabs (Brachyura) of Monterey Bay, California, Leland Stanford Junior Univ. Pub., Univ. Series No. 4, pp. 1-64, 1910.

All species known in the vicinity of Monterey Bay are listed. Littoral and dredged species, from depths of 30 fathoms and under, are included. Fifty-two species are recorded. One is described as new.

Whiteaves, J. F., On some marine invertebrates from the Queen Charlotte Islands, From the Rep. of Progress of the Geol. Survey of Canada, 1878-1879, pp. 1-16, 1880.

The article lists both littoral and dredged species of sponges, Hydroida, Anthozoa, Echinodermata, Mollusca and Annelida.

Wilson, H. V., The Sponges, Mus. Comp. Zool., Harvard, Mem., vol. 30, no. 1, pp. 1-164, 1904.

This paper records sponges collected by the Albatross off the west coasts of Mexico, Central and South America and off the Galapagos Islands during 1891. Forty-seven species and sub-species of deep water Hexactinellida are described.

Ziesenhenne, F. C., Echinoderms from the west coast of Lower California, the Gulf of California and Clarion Island, Zoologica, vol. 22, pt. 3, no. 15, pp. 209-239, 1937.

The article records 65 species collected by the Templeton Crocker Expedition of the New York Zoological Society of 1936. Twenty-eight species are represented by one or two specimens only. The richest littoral stations were at Santa Inez Bay, Gulf of California, and at Sulphur Bay, Clarion Island.

NEW ZEALAND REPORTS ON ECOLOGY AND PALEOECOLOGY

by

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New Zealand is unique in that it has been geographically isolated from other land masses practically continuously since the lower Tertiary. The country is now a mere remnant of a presumed large Mesozoic land mass. Its fauna has developed almost undisturbed by outside influences throughout the Tertiary and to the present. This is reflected in the large percentage of endemic genera and species found in the New Zealand late Tertiary and Recent faunas. Over 1000 miles of ocean (The Tasman Deep) separate New Zealand from Australia.

New Zealand consists of three main islands and a number of off-shore groups disposed between the 34th and 55th parallels. The main islands together form a long narrow land mass, the coasts of which are divisible into well marked faunal provinces.

Aupourian Province. The northern part of the North Island, lying within the zone of Subtropical surface waters and influenced by the ex-tropical East Australian (Notonectian) current.

Cookian Province. Lower part of North Island and upper part of South Island. Mixed waters containing a few of the more tolerant subtropical and subantarctic species.

Forsterian Province. Otago and Stewart Island. Subantarctic waters predominant. Isolated to some extent from the Cookian by long stretches on both coasts of shingle beaches unfavorable to littoral organisms.

Moriorian Province. Chatham Islands, over 500 miles east of the main islands. These are influenced almost equally by warm currents and the cold West Wind Drift. A number of endemic species with Tertiary ancestors in the group points to long isolation from the main islands of New Zealand.

Rossian Province. This covers the groups of Southern Islands lying to the south of New Zealand and entirely within the Subantarctic Zone of surface waters. The fauna is impoverished, containing the most tolerant mainland genera plus a number of widespread Subantarctic elements.

The first three references listed below are primarily systematic, but they give data regarding depth, mode of occurrence, and associations of most of the species of Mollusca inhabiting New Zealand waters. By analogy this information is most useful in the evaluation of Pliocene and Pleistocene faunules.

Suter, H. Manual of the New Zealand Mollusca. Government Printer, Wellington. Pp. 1-1120, 1913.

Bucknill, C.E.R. Sea Shells of New Zealand. Whitcombe & Tombs Ltd., Auckland. Pp. 1-123, 1924.

Powell, A.W.B. The Shellfish of New Zealand. Unity Press Ltd., Auckland. Pp. 1-100, 1937. (2nd Ed., Whitcombe & Tombs Ltd., 1946).

The more important references on New Zealand marine ecology and paleo ecology are arranged below in chronologic order.

Oliver, W.R.B. Marine Littoral Plant and Animal Communities in New Zealand. Trans. N. Z. Inst., Vol. 54, pp. 496-545, 1923.

This is the first descriptive account of the littoral plant and animal communities of New Zealand. The introduction deals with local conditions of habitat, ocean currents, sea-temperatures and tides and general considerations relating to light, evaporation and substratum.

Tables of water temperatures at three locations, northern middle, and southern, are given. The following are the extreme records from these tables:

Auckland	21.1° C. (Jan.)	10.5° C. (June)
Wellington	17.0° C. (Feb.)	9.1° C. (July)
Dunedin	14.6° C. (Feb.)	2.0° C. (June)

Littoral fossil faunules are poorly represented in the New Zealand Tertiary. Raised beaches are common in the Pleistocene, but they have as yet received little attention. When these faunules are given more study Oliver's paper should have a definite application.

Oliver's classification of the littoral formations appears under segregated series of Algae and Benthic animals. This results in a subformation terminology which may be either wholly plant or wholly animal, e. g. Corallina-Hormosira; Cellana-Mondonta.

For the purpose of paleocology a terminology based upon animal names will require to be devised.

Oliver's associations are well described and their recognition in the field is comparatively easy, but a considerably extended scheme will be necessary to cover adequately the whole range of littoral communities. Dr. Oliver admittedly used selected instances to develop his theme and did not aim at a comprehensive classification.

Finlay, H. J. A Further Commentary on New Zealand Molluscan Systematics. Trans. N. Z. Inst., Vol. 57, 1926, pp. 320-485.

The introduction to this important paper summarizes the paleogeographic development of New Zealand; describes the influence of the East Australian current in bringing to New Zealand certain warm water mollusks possessing larval shells of the "sinusigera" type, and names and defines four marine provinces for the New Zealand sub-region.

Marwick, J. Origin of the Tertiary Mollusca of New Zealand. N. Z. Journ. Science and Tech., Vol. 8, No. 5, pp. 269-272, 1926.

"New Zealand Tertiary and Recent molluscan faunas contain South American, Australian and Indo-Pacific elements. The South American influence can for the most part be traced back to the Cretaceous, so that no Tertiary communications are indicated. On the other hand, Australian and Indo-Pacific elements have undoubtedly reached New Zealand during the Tertiary, and may still be arriving. Research is required on the life-histories of the genera and species concerned, and on their power of dispersal, so that the meaning of these immigrations may be properly understood."

Powell, A.W.B. and Bartrum, J. A. The Tertiary (Waitematan) Molluscan Fauna of Oneroa, Waiheke Island. Trans. N. Z. Inst., Vol. 60, pp. 395-447, 1929.

The paper is largely systematic, but specific examples pointing to subtropical conditions for New Zealand in the Miocene are cited, e. g. Pyrazus consobrinus and P. waitemataensis, Isognomon oneroaensis and Morum (Oniscidia) harpaformis.

Finlay, H. J. On Turbo postulatus Bartrum: Does it indicate a Pliocene Connection with Australia? Trans. N. Z. Inst., Vol. 62, pp. 1-6, 1931.

The recognition of "Turbo postulatus" as a short-lived genus of the pelagic Janthinidae. "We have a very short-lived genus existing not in either country, but on the ocean surface between them. Therefore, as its species evolved, it is reasonable to assume that they would be washed up on the shores of each country simultaneously."...."Is it then too much to postulate that this Turbo postulatus allows us to fix a Lower Pliocene base-line from which the correlations of higher and lower beds on either side of the Tasman may be surveyed?"

Finlay, H. J. On Austrossassia, Austroharpa, and Austrolithes, New Genera; with some Remarks on the Gasteropod Protoconch. Trans. N.Z. Inst., Vol. 62, pp. 7-19, 1931.

This paper contains an excellent summary of the work published on the gasteropod protoconch, describes the several types, outlines their probable evolution and indicates criteria of potential value to the paleontologist.

The type A protoconch is tall, narrowly conical, pointed, of about 4 whorls, set slightly oblique to the axis of the shell, entirely coated with a persistent brown horny envelope, strikingly differentiated in color from the rest of the shell. This is the same kind of apex as possessed by Harpa, Neothais, Janthina, and in a wider and lower form by Tonna and Cassis and is very common among tropical mollusks. "It almost certainly represents a Sinusigera, free-swimming embryo".

Type B is polygyrate also, but turbinate with rapidly increasing whorls, polished and without an envelope.

Type C is paucispiral of about two whorls. This resembles B, but the first whorl is irregular and rough surfaced.

Type D is paucispiral of 1-1/2 to 2 whorls, rounded and globose, generally quite small, everywhere smooth and polished and usually marked off from adult whorls by a distinct varix.

These are a few problems mainly concerning one gasteropod family, the Cymatiidae. They emphasize the urgent need for data concerning life histories of mollusks in general for application to paleoecological work.

The following questions require investigation:

"(1) What is the reason for the change from shelly to horny embryo, and can any artificial conditions bring it about?

(2) Why are the horny types apparently more advanced, and in general more characteristic of later geological epochs?

(3) Why are the type A apices practically confined to tropical and sub-tropical seas and so abundant there, while the much older type C embryos are more widely spread? Did the horny type of apex evolve on account of tropical conditions?

(4) Is the type A apex a further evolution from type C or is it very distinct? Why is the chitin so persistent in it and so easily and early lost in type C?

(5) What is the significance of the change from paucispiral type D to polygyrate type B in the shelly series, and from paucispiral type A in the horny series? Do these different embryos show any notable difference in swimming powers, and hence distribution?"

Powell, A.W.B. On Some New Zealand Pelecypods. Proc. Malac. Soc., Vol. 20, pp. 70-72, 1932.

The littoral bivalve Anadara trapezia is still living in the sub-tropical waters of Queensland, New South Wales and the Great Australian Bight. As a Pleistocene fossil it occurs abundantly in Southern Australia and Tasmania. It is no longer living in New Zealand, but odd valves wash ashore on the beaches of the North Auckland Peninsula, and a bed in situ was discovered in Pleistocene muds at Kohukohu, Hokianga Harbor. In Australia wherever the species occurs living it is gregarious. It is found half exposed on tidal mud-flats. Hedley suggested in 1915 that exposure to the air without the protection of the substratum afforded to burrowing littoral mollusks would make this species the first victim of lowered temperatures. Hedley's contention was that the southern distribution of Anadara was destroyed in this way and that the species survived only by virtue of its subtropical Queensland range. With the return of warmer conditions in New South Wales the species was again enabled to extend southward.

Recently an example of Anadara trapezia with conjoined valves was brought up from six fathoms near Awanui on the opposite side of the island from Hokianga, which is on the west coast. Since Anadara is of strictly intertidal occurrence, this record becomes a valuable piece of corroborative evidence of a North Auckland east coast negative movement differential to the West Coast which at the Kohukohu bed is still at mid-tidal level.

Allan, R. S. The Fauna of the Reefton Beds (Devonian) New Zealand. N. Z. Geol. Survey, Paleon. Bull. No. 14, pp. 1-72, 1935.

A summary of world-wide Devonian marine faunas is given for comparison with the Reefton Beds. "Lower Devonian marine faunas of the same age can be subdivided into a number of characteristic animal communities, each of which seems to have existed under and to have been bounded by a distinct set of physical conditions."

Hounsell, W. K. Hydrographical Observations in Auckland Harbor. Trans. Royal Soc. N. Z., Vol. 64, pp. 257-271, 1935.

Contains the hydrological data relevant to the above paper.

Powell, A.W.B. New Species of Marine Mollusca from New Zealand. Discovery Reports, Vol. 15, pp. 153-222, 1937.

A fifth marine province, the Auburian, is introduced and all five are more precisely defined.

Powell, A.W.B. Animal Communities of the Sea-bottom in Auckland and Manukau Harbors. Trans. Royal Soc. N. Z., Vol. 66, pp. 354-401, 1937.

This is the first evaluation of benthic animal communities in New Zealand, but in scope it is restricted to the Auckland district. The work is descriptive of the animal communities found in that area and these are named and diagnosed.

Samples of the substratum from all dredge stations were mechanically graded and the results reduced to an average texture for each station. Texture curves were distinctive for each community and a correlation between type of bottom and animal community became apparent. The texture determinations were achieved by using six sieves with round holes, in the following descending order of size - 15 mm., 5 mm., 2.5 mm., 1.5 mm., 1 mm., and 0.5 mm. diameter. Two further grades were separated from the residue, i.e. material settled in 1 minute (fine sand) and material still in suspension after 1 minute (silt). All eight grades were dried and weighed, and the individual results expressed as percentages of the total dry weight. Average texture for each sample was determined conventionally by multiplying the weight of each grade by the number of the sieve (No. 1 = 15 mm. holes, No. 2 = 5 mm. holes, etc.) and dividing the sum of the eight weights by 100; the result provided a numerical indicator which afforded a ready means of comparing samples.

Four main Recent animal communities (formations) were found in the area under survey and they are listed below together with their texture figures.

1. Echinocardium formation. Average texture 7.215. Fine sand and silt (grades 7 + 8) 93.81 percent.
2. Macricolpus formation. Average texture 3.425. Fine sand and silt, 24.01 percent.
3. Tawera + Glycymeris formation. Average texture 2.668. Fine sand and silt 2.81 percent.

4. Arachnoides formation. Average texture 6.769. Fine sand and silt, 94.79 percent.

Subsidiary communities (associations) each have their distinctive textures.

Summary for each of the four main formations:

1. Echinocardium formation. The maximum number of species listed for this formation and its associations is 59 and the average number for all stations 7.3. The microfauna is only barely represented.
2. Maoricolpus formation. The maximum number of species is 62 and the average for all stations 25.57. The microfauna comprises 14 species and is rich numerically. The salinity of the water in which this formation occurs is lower than that of the three other formations considered.
3. Tawera + Glycymeris formation. The maximum number of species is 142 and the average for all stations 39. The microfauna comprises 21 species and is rich numerically.
4. Arachnoides formation. The dominant animal is the cake-urchin, Arachnoides. The fauna is sparse both in species and in numbers, and the microfauna is poorly represented.

A table is given showing the intercommunity range of certain animals correlated with the substratum. It was found that certain animals were restricted to one animal community, while others occurred in several irrespective of the texture of the substratum, which often covered a range from soft mud to hard shell-sand. It is of interest to note that the deposit feeders have the least range and are invariably confined to one texture of bottom, this being not surprising since the substratum is intimately linked with their food. Suspension feeders and herbivorous feeders both have a greater range, but show their optimum development in one particular texture of substratum. Carnivores have no particular preference in relation to substratum since they are predatory on a number of animals and are not directly concerned with the substratum in which their food lives. Similarly suspension feeders may occur in a variety of grades of substratum for the same reason.

Diagrams of two sections are given to illustrate succession in the animal communities. There are two main processes operating in Auckland waters which achieve a succession from soft to hard bottom. One, a reversal of the normal principles of deposition, results in the coarsest material being deposited furthest from shore. This applies only in tidal channels, the current being responsible for dragging down shell debris from soft-bottom areas at the sides until the deposition of a zone of clean-swept coarse shell-gravel results in the middle of the channel or wherever the tidal current is greatest. The other process which is typical of exposed rocky coasts and off-shore islands, operates in the normal way, the coarse shell-gravel occurring closest inshore and the comminuted grades further out in descending order of fineness, until soft bottom is reached.

Powell, A.W.B. Notes on the Importance of Recent Animal Ecology as a Basis of Paleoecology. Proc. Sixth Pacific Science Congress, 1939.

This paper gives a precis of the 1937 animal community paper with an indication of the manner in which the results may be used in the better

interpretation of New Zealand Pliocene faunules. Three of the formations designated in the 1937 paper are recognisable in the Castlecliffian Upper Pliocene. The Arachnoides formation is present in sandy beds interpolated with mudstone bands containing a benthic fauna. Since Arachnoides lives in shallow water, is restricted to an even fine grade sand substratum, and occurs in waters of normal salinity just within the entrance to a harbor or estuary, this species is not only a good depth indicator, but is of special value in paleogeographical reconstructions.

Finlay, H. J. and Marwick, J. The Divisions of the Upper Cretaceous and Tertiary in New Zealand. Trans. Royal Soc. N. Z., Vol. 70, pp. 77-135, 1940.

Under each stage name much information useful to the ecologist is given. The headings are: "Type locality, Sediments, Fauna, and Correlatives". The fauna is dealt with under the following subheadings: "Restricted forms, First appearance of, and Last appearance of".

A revision of the above paper by the same authors is in progress. There will be some changes in the Lower Tertiary sequence.

Allan, R. S. The Origin of the Lower Devonian Fauna of Reefton, New Zealand; with Notes on Devonian Brachiopoda. Trans. Roy. Soc. N. Z., Vol. 72, pp. 144-147, 1942.

Fresh evidence has caused Dr. Allan to revise his 1935 hypotheses regarding the origin of the Reefton fauna as follows: "The Origin of the Lower Devonian fauna of the Reefton Beds is to be explained by migration along shorelines by a route or routes still imperfectly known but of which the most probable and important was the Tethys sea-way".

Fleming, C. A. Molluscan Evidence of Pliocene Climatic Change in New Zealand. Trans. Royal Soc. N. Z. Vol. 74, pp. 207-220, 1944.

"Faunal changes in the New Zealand Pliocene suggest that late Tertiary lowering of sea temperatures reached its peak in the mid-Pliocene, when sub-antarctic water extended northwards to southern Hawke's Bay, bringing a characteristic cold water fauna. In the Upper Pliocene, further advance of cold water isotherms was prevented by a new factor, the Notonectian subtropical current, which has continued to affect New Zealand coasts, bringing a fauna of East Australian warm-water mollusks, and driving sub-antarctic waters and their fauna south to their present position. New Zealand Mollusca did not suffer changes commensurate with the severity of the Pleistocene glaciation. This anomaly may be due to the persistence of the warm current influence through the Pleistocene, so that the low air temperatures of the Glacial Period failed to affect the marine fauna."

"An extinction which can be attributed to Pleistocene cooling is that of Anadara trapezia.

PALEOECOLOGY IN WESTERN AUSTRALIA

by

Curt Teichert[2/]

Western Australia is one of the six States of the Commonwealth of Australia. It covers almost one million square miles (one-third of the continent) and of these roughly one-third, or 330,000 square miles are underlain by sedimentary rocks of later than Pre-Cambrian age. The extent of many sedimentary areas is very inadequately known so that the figure given for their size must be taken as a very rough approximation.

As a member of the staff of the University of Western Australia from 1937 until 1946, I was in a fortunate position in that I was able to carry out stratigraphical and paleontological research in all parts of the State. These researches were financed by the Commonwealth Research Grant to the University of Western Australia under the general supervision of the Council for Scientific and Industrial Research. The primary objective of most of this work was to gather stratigraphical information, to establish standard sections in some of the most important areas, and to attack the problem of intra-West Australian and foreign correlations with the aid of sound paleontological data. There was thus little time for paleontological work, either systematic or ecological, except insofar as it had a direct bearing on the problems stated above.

The following is a very brief statement of some of the problems of paleoecological interest encountered in the course of this work. Pressure of other work prevents me from elaborating further on any of these observations and the only justification for offering this sketchy and rather inadequate summary to the general reader may be found in the fact that information of this kind has not previously been forthcoming from this part of the world.

A general paper on the stratigraphy of Western Australia has been accepted for publication by the American Association of Petroleum Geologists. This will contain maps and photographs which the reader may wish to consult.

1. Cambrian

Cambrian shales and limestones occur in the extreme northeast of the State and extend from there into the Northern Territory where their extent and stratigraphy are almost entirely unknown. One of the most remarkable formations of this sequence is almost entirely composed of Girvanella. The main bed forms a biostrome, about 10 feet thick, which can be traced for over 100 miles and must originally have covered thousands of square miles. A second Girvanella bed follows somewhat higher in the sequence, but is now mostly eroded away. Both beds belong to the Redlichia zone of the Lower Cambrian, though the associated fauna is very poor.

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The most common associate is a small conical shell, now generally known as Biconulites hardmanni. In a great many cases these little shells are found telescoped into one another, indicating that they have been moved and rolled about by the waves. In another limestone formation, on the Linacre River, not associated with the Girvanella beds, ripple marks were observed whose ridges were entirely composed of innumerable shells of Biconulites.

These observations indicate that all the beds, including the Girvanella biostromes, were deposited in very shallow water, probably of less than 50 or 60 feet.

2. Devonian

Devonian rocks occur in the western part of the Kimberley Division, in the northern part of the State. Two biofacies are of particular interest, viz. "reef" facies and goniatite facies.

A. "Reef" facies. - In the Middle Devonian we find biostromes several hundred feet in thickness composed of the small branching stromatoporoid Amphipora ramosa, associated with Thamnopora, Stachyodes, and other forms. In the late Middle and in the Upper Devonian their place is taken by a bioherm facies with massive stromatoporoids predominating. Associated reef-builders were Receptaculites, Thamnopora, and rugose corals (mostly Prismatophyllum). These reefs now crop out in the Napier, Oscar, and Geikie Ranges, in a narrow belt, about 200 miles long. The exposures are excellent and offer probably the best opportunity for the study of Palaeozoic bioherms in Australia.

B. Goniatite facies. This is rarely associated with the reef facies, but occurs in the main in a separate belt to the east of it, and is at present best known from the vicinity of Margaret River and Mount Pierre Creek. The characteristic rocks are "red beds" that are red, or banded red and green, or red and grey, calcareous shales and calcareous sandstones, occupying a belt, originally probably of lagoonal nature, between the reef belt and the near-shore area with its coarse clastic sediments. These sediments contain a fine series of goniatites which closely parallels the early and middle Upper Devonian goniatite series of Germany (Manticoceras, Cheiloceras, Sporadoceras, and others, later associated with clymenids). The goniatites are strictly confined to this lagoonal facies. Temporarily and locally small stromatoporoid bioherms were built in this belt and goniatites are then usually found in their vicinity. In one particular series of outcrops of several small reefs along the strike of the rocks, the goniatites (large specimens of Sporadoceras) and associated nautiloids were invariably found on the same side of the reefs, probably the side which offered shelter from the predominant currents or waves in the lagoon. Although goniatites thus flourished in the vicinity of the small reefs of the lagoonal belt, they are never found in the main, outer reef belt, the proper "reef facies".

In general it is concluded that goniatites must have been benthonic, or necto-benthonic animals which preferred the habitat of open, rather shallow seas, and, since they are often found in the rocks to the exclusion of almost any other kind of fossil, they must have been able to live under conditions which were disagreeable to many other animals. Perhaps they were able to feed on poorly aerated bottom regions, periodically ascending to the better aerated upper water layers.

3. Permian

The exact size of the area covered by Permian rocks is unknown, but is almost certainly very great, perhaps of the order of 150,000 square miles or even more. Observations of paleoecological interest have been very scattered and disconnected.

The general relationships of the faunas are with those of Timor and of the Salt Range of India (Productus limestone). The number of species is very considerable and might approach that of Timor, with the exception of the crinoids and ammonoids. Of the latter less than a dozen species are known, but nonetheless it is the only Permian ammonoid fauna of any consequence in Australia. Most of the forms are typically Artinskian and this aspect is further strengthened by the associated fauna which includes the shark Helicoprion.

Of considerable interest is the Permian sequence of the North-West Basin, the only wholly marine Permian section in Australia. About 10,000 feet of shales and sandstones were here deposited almost entirely in Sakmarian and Artinskian times.

A special study was made of the genus Calceolispongia, a most peculiar and remarkable crinoid with greatly enlarged, horn-shaped and spinose basal plates. This most unusual genus is rare elsewhere, but has had a meteoric career in Western Australia where it appears with small species in the beginning of the Artinskian and develops rapidly through a succession of about ten species in about 7,000 feet of sediments into one of the bulkiest and weirdest crinoid species of all times. Almost invariably this crinoid occurs in large numbers. It must have existed in huge colonies, often crowding out other forms of life. Their great bulk caused the plates to become dissociated very soon after the death of the animals which in many cases must have been catastrophic, large colonies being wiped out simultaneously by suddenly formed layers of sediment. Sometimes, however, sediment accumulated so rapidly that the entire cups were preserved which could have happened only if the skeletons were completely buried before the animal tissue that held the plates together decayed.

Other observations were concerned with the boring of many shells, chiefly brachiopods and pelecypods, by parasitic worms of which several different varieties were recognized.

A very common feature in Permian beds is the occurrence of a great variety of types of invertebrate tracks. Two of the most common types were illustrated in 1941. One is a large segmented track, composed of more or less globular segments, joined together. This was believed to have been due to a very large mud-eating worm. The other type appears in several varieties, mainly differing in their size, but all have a characteristic middle furrow and are obviously made by animals that moved with the main part of their body through the sediment, but with some part sticking out above the surface of the sediment, leaving the central furrow. Similar tracks have been described by Abel as having been made by living gastropods (Bulla). A very common track of the Nereites type has not yet been studied, together with other complicated as well as simple types.

Burrows also appear in some variety. Plain vertical cylindrical burrows are known from certain sandstones, but of greater interest are U-shaped burrows of which there are two types: parallel with and vertical to the bedding planes. In general these burrows are of the Rhizocorallium type. Some of them show perfectly preserved scratch marks similar to marks attributed to decapods by Weigelt some years ago.

On the land the Glossopteris flora predominated. Next to Glossopteris the most important member was Gangamopteris. It seems that the latter has a somewhat more restricted distribution, being absent from the Kimberley Division. Since the genus is also unknown from northern Queensland and its northern distribution is similarly restricted in South Africa, it may be that Gangamopteris was restricted in its distribution to colder areas. This, however, leaves its occurrence in India unexplained, at least on the basis of the present arrangement of the continents.

In conclusion I wish to emphasize that there is a virtually unlimited field for paleoecological studies in the Permian of Western Australia, of which not even the surface has been scratched.

4. Jurassic

Jurassic rocks occur in plant-bearing lacustrine as well as in marine facies, the latter including rocks of Middle and Upper Jurassic age.

The Middle Jurassic rocks belong to the Bajocian stage and are best known from the vicinity of Geraldton where calcareous sandstones and shales occur in richly fossiliferous development. There is a promising field for ecological research in the study of faunal differences between the shaly and the sandy facies. An interesting algal facies occurs in rocks of the same age in the North-West Basin, several hundred miles farther north, but the outcrop is so limited that no general conclusions can as yet be drawn.

Our knowledge of the Upper Jurassic is similarly limited, rocks of this age being known from bores in the Kimberley Division only. They are an interesting extension of the Buchia-Belemnopsis facies of the East Indies.

5. Cretaceous

Rocks of this age have a wide distribution in Western Australia and the common occurrence of chalk over large areas raises many interesting problems. Chalk occurs scattered in the southwest (Southwest Coast Basin), but is more important further north where it extends as an uninterrupted belt, partly buried, partly exposed on the surface, from the vicinity of the Murchison River for about 400 miles as far as Exmouth Gulf. The bulk of this chalk is of Senonian age, although some of it seems to belong to earlier periods of the Upper Cretaceous. Throughout its entire length this belt is characterized by a faunal association in which Uintacrinus and Marsupites are prominent. The associated fauna, though locally rich in individuals, is comparatively poor in the number of species. It contains brachiopods, pelecypods, one or two echinoids, some crustaceans, and a few ammonoids, most of which are poorly preserved. The beds contain a rich foraminiferal fauna which, however, is in need of modern revision.

The chalk deposits of Western Australia are probably the most extensive of the southern Hemisphere. Although the northern end of the chalk belt reaches north of the Tropic of Capricorn, most of it lies in the temperate zone. We are then confronted with the remarkable fact that almost all chalk deposits in the world are of Upper Cretaceous age and situated in the two temperate belts. This suggests that the formation of chalk proceeded under a special set of conditions, not at all well understood, which existed only during a comparatively limited period and was operative in two belts which coincide with the temperate belts of the present day. This rather suggests that climatic belts of Upper Cretaceous time might have been similarly aligned to those of the present day. Ecological investigations of the Western Australian chalk deposits would materially contribute to the further elucidation of these problems.

Associated with the chalk are greensands with scattered low grade phosphate deposits, which at Dandaragan yield remains of ichthyosaurian and plesiosaurian reptiles.

Near the mouth of the Murchison River thick delta deposits of Cretaceous age are characterized by vertical burrows as well as by invertebrate tracks on bedding planes as the only evidence of fossil life in these deposits.

6. Tertiary

Tertiary deposits cover fairly large areas in various parts of Western Australia, though very little is known about their fauna and detailed stratigraphy. In the northwestern coastal belt Eocene, Oligocene, and Miocene occur in foraminiferal facies. Bryozoan and coral limestones are also known.

In the southeast a large perfectly flat area, the Nullarbor Plain of some 20,000 square miles, is covered with Miocene limestone mostly in shelly and bryozoan facies. In the middle of the plain, however, at Forrest, reef-building corals occur, but the occurrence, which is far removed from any known similar facies of that age, has not yet been properly investigated.

The Miocene was a period of wide-spread transgression of the sea in Western Australia. Considerable portions of the Pre-Cambrian shield were then submerged and erosion remnants of the deposits laid down by this sea are found as scattered outcrops. One of the most interesting areas is at Norseman, over 100 miles from the south coast. In addition to fossiliferous limestones a sponge spicule deposit is found here occupying a depression in the Pre-Cambrian surface. Sponges must have been very important among the Miocene faunas of Western Australia, for a rich sponge deposit containing a considerable variety of well preserved sponges is also known from places nearer to the coast. The ecology of these Tertiary sponge faunas remains to be worked out.

7. Pleistocene and Recent

The ecology of coral reefs offers the most interesting problems in these periods. The coral reefs of Western Australia are among the least known in the world, although they extend over many degrees of latitude, include many different types of reefs, and among them are the most southerly situated coral reefs in the Indian Ocean.

In 1944 I investigated parts of Houtman's Abrolhos, a group of coral reefs 40 miles off the coast, about 300 miles north of the latitude of Fremantle, and studied paleoecological as well as ecological aspects. The history of the islands is bound up with the eustatic changes of sea-level in Pleistocene and Recent times which cannot be discussed here. The reefs are built around cores of Pleistocene and Recent times which cannot be discussed here. The reefs are built around cores of Pleistocene coral reefs now mostly raised 5 to 8 feet above sea-level. The most important constituents of these reefs are various species of Acropora, Favia, Favites, and Platygyra ("Coeloria"), but a systematic study of their ecological relationships has not yet been attempted. Since fossil coral reefs of the same general type and in similar geological settings are found as far south as 32° S. lat. it is concluded that they were all formed during some specially mild interglacial period of the Pleistocene.

The living reefs of the Abrolhos group are characterized by the comparatively small number of species. A preliminary survey of recent corals shows the number of species to be in the vicinity of 25, as compared with some 80 or 90 species in typical coral reef associations of the East Indies. Even this number seems large considering the extreme marginal position of the reefs. Summer temperatures of the sea are only little above 20° C. and it seems that at least locally water temperatures must fall considerably below 20° in winter time. Algae are important in the constitution of these reefs, though hardly more so than has been described from many reefs of the tropical belt. The "Lithothamnion rim" was found in typical development in some of the Abrolhos reefs. The general conditions of reef growth are discussed in a paper to which the reader must be referred. In the course of these investigations, the present distribution of reef corals on the shelf south of the Abrolhos group was reviewed. There is vigorous growth of Pocillopora in localities as far south as 32° S. lat. and records of other reef corals (Turbinaria) exist from even more southerly localities.

The Pleistocene and early Recent offer many more problems of paleoecological interest, as for example the existence of rich marine shell deposits in the Swan River estuary, coquina layers on Rottnest Island, and others which have as yet received little attention.

The ecology of the present coasts of Western Australia should provide much interesting material for the geologist but the field has not been touched. For example, in the large embayment of Shark Bay and its southern ramifications, Freycinet Inlet and Hamelin Pool, sedimentation now proceeds under extreme shallow-water conditions (generally less than 10 fathoms) in a sub-tropical climate and adjacent to the coasts of a semi-arid land with periodically flowing rivers. Many imperfectly understood deposits of the geological past may have accumulated under similar conditions and many lessons may have to be learned from a study of these Western Australian coasts. In the inner parts of Hamelin Pool a unique deposit is now accumulating along many miles of coast. This is composed of shells of a small species of Cardium, almost to the exclusion of any other species. The reasons for this accumulation are at present unknown, but the conditions which led to it must have developed in comparatively recent times, because a few feet below the surface the assemblage, though still of a pure coquina type, becomes much more varied in composition.

Similarly interesting ecological investigations may be taken up on the land, where the many salt lakes of Western Australia offer a variety of interests. Earlier authors have discussed the significance of the occurrence of Coxiella, a small euryhaline gastropod capable of surviving under conditions of highly increased salinity. More recently the effect of algal growth in the surface layers of the clay floor of a dry lake was studied. This growth led to a characteristic crumpling of the surface which might easily be preserved in a fossil state and which was indeed found to be similar to certain structures described from Tertiary sandstones in Bavaria.

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METHODS OF STUDY OF RECENT FORAMINIFERA

by

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The distribution of Recent Foraminifera usually has been studied from the distribution of the empty tests obtained from marine sediments. These sediments usually have been obtained by various types of bottom samplers which sample an unknown area and depth of the bottom materials and obtain a sample which is not necessarily representative of the materials which are accumulating on the surface. There have, of course, been a few exceptions to this procedure. Few attempts have been made to study the distribution of living populations.

In studying living populations, the pelagic and the benthonic types must be treated separately, and they should be collected and analyzed in a quantitative, rather than a qualitative, manner. The procedure for collection and study of pelagic forms has been discussed by the writer in a previous report of this Committee (No. 2, 1942, p. 6-9).

Recently a new technique has been worked out for collection and similar study of benthonic forms. This has been successfully applied in sedimentary studies which are being conducted in the Gulf of Maine, off Portsmouth, N. H., by the Woods Hole Oceanographic Institution. The following is only a partial report of these studies since the laboratory work on the material which has been collected has only begun.

A bottom-sampler has been designed which is a small, lightweight coring tube. This obtains a relatively undisturbed sample a few inches in length which preserves the surface of the bottom as well as a short column of water above the bottom. The sample is contained in a plastic tube 1½ inches in diameter which is the liner of the coring instrument. A small amount of neutral formaldehyde is added to the sea water above the sample. The plastic liner tube is a convenient container for transporting the sample; the sample must be kept in an upright position during transportation and storage to avoid mixing of the surface materials. This sampler works successfully in mud or mud-sand bottoms, and can be used with a light-weight, high-speed winch.

In the laboratory, the upper half inch of the sample is removed and washed through a fine-mesh bolting silk, carefully keeping the sample wet at all times. The washed sample is then placed in a small container with water, and one of the tests used by physiologists for protein is applied. The biuret test for protein, in which the protein-bearing substances become purple in color, was described in a previous Committee Report (No. 2, p. 8, 1942). This has not proved to be a complete success with benthonic material, although it is satisfactory with pelagic material. The reason for this is not at all clear. The test for protein using Millon's Reagent is excellent when applied to arenaceous specimens. Since Millon's Reagent contains considerable free

nitric acid it will dissolve the calcareous tests. It is possible to identify the calcareous specimens before using the solution, and later identify those which contained protoplasm from the protoplasmic casts. This, however, is a laborious and not entirely satisfactory procedure. Samples from areas of mud bottom which have been examined from off Portsmouth, N. H., have fauna composed entirely of arenaceous forms. Millon's Reagent thus is an excellent test for this material.

FISH REMAINS IN RECENT DEPOSITS OFF THE SOUTHERN CALIFORNIA COAST

by

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An abundance of fish remains, especially well-preserved scales, has been found in the sedimentary rocks of the Pacific Coast of North America. Such material occurs in strata ranging from the Upper Cretaceous to the Pliocene, and in an area from Northern Washington to the Imperial Valley of California. The ecological significance of these occurrences would be better understood if we knew more about the abundance and distribution of fish material in Recent deposits. So far as we know, however, no investigations of this kind have ever been undertaken.

We do have a fairly good knowledge of the distribution of assemblages of living fish in different realms of the ocean, thanks to investigations undertaken during past decades. This knowledge has been useful in work with fossils. It suggests that the fossil deposits of the Pacific Coast were formed in fairly deep water--there is evidence of assemblages of deep neritic environment all the way down to abyssal environments. Shallow-water deposits are very rare but single scales of shallow-water fishes are found occasionally. An especially close similarity exists between the abundant bathy-pelagic faunas of Upper Miocene age in California and the Recent faunas of such environments in the Pacific Ocean. (David: Bull. G.S.A., Vol. 55, 1944, pp. 1467, 1468.) However, in the latter case, completely-preserved fish play an important role.

Some assemblages consist entirely of scales and must be considered from a different point of view; in general such assemblages are composed of only a limited number of forms representing only part of the total fish fauna present in corresponding environments of the ocean today. It is in this connection that the study of fish remains in Recent deposits may be of great value.

To investigate the possibilities of this type of research, we looked through samples of Recent deposits collected by Manley L. Natland, in the Catalina Channel, between 1926 and 1933. These samples were taken in order to determine the distribution of Foraminifera in Recent sediments. A majority of them are small grab samples and show no fish remains of importance. Many that were taken in shallow water show fish remains only in a very few instances. (These are not listed below).

Following is a list of some samples that contained significant and well-enough-preserved fish remains:

a) Drag samples, taken in the Catalina Channel with a small wire drag, covering considerable distances and undertaken largely to catch Mollusca: These samples contained Mollusca, generally small or fragmentary, numerous worm tubes, brittle stars, corals, sponge spicules and others, but comparatively few Foraminifera.

Sample 163: Taken off Balboa in the Catalina Channel, location 33° 34' 30" latitude and 117° 53' 55" longitude, at a depth of 630 feet, 192 m., on July 29, 1933.

Fish remains present are: Numerous bones and vertebrae; Sardinops coerulea, the pilchard, 12 scales, 5 smaller fragments; Pneumatophorus diego, the mackeral, 1 scale; Atherinops californica, smelt, 1 scale; undetermined Sciaenid, croaker, 1 scale.

Sample 144: Catalina Channel at 770 feet depth, 231 m., in 88° bottom temperature at 33° 35' 45" latitude and 118° 16' 20" longitude.

Fish remains present are: Sardinops coerulea, 32 scales--about two-thirds of these large scales are to some degree fragmented; 2 ventral scutes of the same species; Pneumatophorus diego, 3 scales; Salmo sp., 1 scale: Sebastodes sp., rockcod, 2 scales; ?Sebastodes sps., 5 scales; Merluccius productus, hake, 8 scales.

Sample 139: Catalina Channel at 825 feet depth, 247.5m., locality 33° 39' 25" N. latitude and 118° 16' 49" W. longitude.

Fish remains present: Numerous bones and vertebrae; Sardinops coerulea 30 to 35, scales, partly fragmented; Pneumatophorus diego, 2 scales; Merluccius productus, 2 scales; Sciaenid fish, 1 or 2 species, 5 scales; Sebastodes sp., 2 scales.

b) Samples 152 A and B taken in the Catalina Channel, evidently in a deep submarine canyon, on March 4, 1933.

152 A: at 518 m. depth, at a locality 33° 39' 00" latitude and 118° 18' 25" longitude, with a bottom temperature of 6.2° C.

Fish remains present: Bones and vertebrae common; fish teeth rare; Sardinops coerulea, 3 scales and 20 or more small fragments; Merluccius productus, 3 scale fragments; Pneumatophorus diego, 2 scales; undetermined Myctophidae, large scaled species, 2 scales, small scaled sp., 2 scales.

152 B: at 1840', or approximately 561 m., at a locality 33° 38' 40" latitude and 118° 18' 35" longitude, 6.0° C. bottom temperature.

Fish remains present: Common bones and vertebrae; Sardinops coerulea, 1 scale, 10 or more smaller fragments; Merluccius productus, 1 scale; Pneumatophorus diego, 1 scale; undetermined Myctophidae, large scaled species, 1 scale, small scaled species, 1 scale. The quantity of material studied of this locality was less than of 152 A, which accounts for the difference in numbers of scales found.

Sample 137: Taken near 152 but at shallower depth, 472 m., at a locality 33° 33' 17" N. latitude and 118° 15' 40" W. longitude, with a bottom temperature of 6.4° C., on August 8, 1932.

Fish remains present: Few bones and vertebrae; slender curved fish teeth, 4; Clupeid scale fragments, 5 or more; Pneumatophorus diego, 2 scales; Merluccius productus, 1 scale. Fish remains present only in moderate abundance.

c) Sample 109, taken near the deepest part of the Catalina Channel, at 2860 feet depth, approximately 758 m., at a locality of 118° 19' 50"W. longitude and 33° 26' 40" N. latitude.

Fish remains present: Numerous bone fragments and vertebrae; fish teeth; small fragments of Clupeid scales, evidently of the pilchard Sardinops 15 to 20; Merluccius productus, 1 small fragment showing center of scale Gadoidea, cod fishes, ?Bathygadus sp., 2 scales, fragmented; Myctophoidea, lantern fishes, large scaled species, 4 scales; undetermined Iniomi, 2 species, 4 scales and 2 scales.

The difference in ecology between this last sample and the a samples is very evident. The only well-preserved scales in Sample 109 are those of bathyal fish, whereas the a samples show a number of the large-scaled forms of the neritic facies. Samples 152 show bathyal forms but also some fairly-well-preserved scales of neritic forms.

The few records we were able to give above do allow us to derive some very helpful facts:

1) Well preserved fish remains are present in Recent sediments. 2) Dragging the ocean floor with a canvas drag seems an efficient way to collect t ese remains. 3) Common fish remains were found at certain localities only; these varied in depth between 192 to 758 m., the latter being the deepest area from which samples were available. 4) There are significant differences between assemblages collected in different environments. 5) Similarity to Tertiary fossil assemblages that are known from Southern California, is quite evident. (See David, Carnegie Institution Contributions to Paleontology, Publ. 551, III, IV, V). The fish remains in the Recent sediments show more similarity to California Pliocene or Uppermost Miocene (Delmontian) assemblages, than to any other fossil faunas known. In the Pliocene, however, as we have stated before, fish remains are quite rare as compared to sediments of earlier ages. The fish remains include: lantern fishes (Myctophidae); two Clupeid fishes, one similar to Ganolytes, the other more closely related to a small sardine; gadoids, as hakes (Merluccius) and Bathygadus; a Sciaenid, possibly Cynoscion: a smelt, Atherinopsis and others. (See Fourth report of Committee on Marine Ecology, pp. 30-31, 1944).

DISTRIBUTION OF ORGANISMS ON BANKS AT THE MOUTH OF WAKASA BAY, JAPAN SEA AND ADJOINING CONTINENTAL SHELF

by

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The bottom topography of the sea surrounding Japan is quite complicated, there being numerous banks on and near the continental shelf around the chain of the Japanese Islands. Those peaks on the sea bottom provide important fishing centers and are of special interest from the point of view of oceanography, being amply endowed with a variety of oceanic conditions and exhibiting notable peculiarities in the distribution of fauna and flora. Furthermore, the submarine deposits surrounding the bank show somewhat different characteristics from the ordinary deposits on the continental shelf. The Urashima, Gentatsu, Matsudashi, Oguri and the other banks are located at the mouth of the bay which lies longitudinally along the coast of Honshu. On the continental shelf near these banks there is a scattering of islands and small banks. Large rivers flow into the sea and render this area an admirable place for a comparative study of the bottom character and the distribution of organisms between the bank and the continental shelf.

The Oceanic Condition of the Wakasa Bay

In the summer season, the temperature and salinity are respectively 26° C. and 32.4‰ at the surface to 50 m. and 19° C. and 34.6‰ below 50-100 m. The surface water of high temperature and salinity belongs to Tsushima current (warm current) but below 200 m. there is a cold water mass peculiar to the Japan Sea, with the temperature of 0 to 3° C. and a salinity of 34.5‰. The oceanic current in the bay flows with a speed of 1.5-2 km./h off Kyogasaki and 1.5 km./h at Antozaki at the mouth of the bay. Within the bay the current forms a large whirlpool with a speed of 1.4-1.0 km/h at the depth of 50 m. and of 0.1-0.3 km./h at the depth of 200 m.

The Bottom Character of the Bay

The rocky floor is exposed most commonly on the banks and the surrounding area. On the continental shelf, the rocky floor is exposed in some places on the islands, small banks and their environs and also in the shallow part near the coast.

Gravels are found on the banks and their environs and also on the continental shelf, but rarely in the depression between the banks and the continental shelf.

Sand and mud on the sea bottom change gradually from coarse to fine as depth increases, but on some elevations like banks and their surroundings the sediment is much coarser than on the shelf at the same depth.

Distribution of organisms on the banks at the mouth of Wakasa Bay and their adjoining continental shelf.

Excluding micro-organisms, it was found that macro-organisms occurred in the bottom samples from 258 points from the total of 623 stations.

154 species of pelecypods were found at 277 stations. They were most abundant at depths of 40-60 meters and in regions where the bottom materials are coarse grained. Some species were confined to limited areas, for example, Lima goliath Sowerby occurred only on the banks and Nuculana gordonis Yokoyama on the continental shelf.

168 species of gastropods were found at 159 stations. They were most abundant at depths of 40-60 meters and were approximately equally abundant on various types of bottom, from coarse gravel to mud. In general, they were most abundant on the banks and in river estuaries.

16 species of scaphapods were found at 87 stations, principally on the continental shelf. They were most abundant at depths of 220-240 meters on a bottom of gravel and sand.

3 species of pteropods were found at 72 stations, principally at depths of 80-100 meters on a bottom of gravel and sand.

17 species of brachiopods were found at 73 stations, mostly on the continental shelf at depths of from 100 to 140 meters on a bottom of gravel and sand. The geographic distribution of the brachiopods is very narrow and much more restricted by depth and character of the bottom than other organisms.

17 species of anthozoa were found at 91 stations, mostly at depths of 40-60 meters from rocky bottoms on banks and from coarse sandy bottoms on the continental shelf.

21 species of echinoderms were found at 64 stations, mostly at depths of 100-120 meters from gravelly and sandy bottoms on banks.

Annelids, bryozoans, porifera and fish were minor elements in the faunas obtained.

32 species of algae were dredged from 19 stations, mostly at depths of 40-80 meters.

Comparison of the distribution of organisms between the continental shelf and the banks.

Bottom samples with organisms collected were grouped for every 20 meters deep. The dredge stations are few on the banks between the depth of 0-60 m., while on the continental shelf they are extremely numerous in the same bathymetric range but less in number at depths greater than 180 m.

The result of the comparison shows that the stations on the banks have a large number of species as well as a large number of individuals, but it must

be noted that the distribution of organisms is affected by the nature of the bottom. Therefore my comparative study was carried out on the same kind of bottom and the same depth range.

Comparison of the distribution of organisms in cold and warm water type.

In this study, animals and plants occurring in central Japan were not taken and only boreal and austral organisms were taken into consideration. Austral or warm water forms found were 6 spp. of pelecypoda, 4 spp. of gastropoda, while boreal or cold water forms 11 sp. of pelecypoda, 6 spp. of gastropoda, 1 sp. of anthozoa, 1 sp. of algae.

1. The austral type are mostly found in the shallow parts of the bank and in the vicinity of capes.

2. Boreal forms occur on the slopes of the shelf and the banks.

3. The number of species of organisms of two kinds are generally about the same on banks. On the shelf and off shore on the bank, the boreal species are more numerous than austral ones, the reverse is the case in the shallow part of banks and the cape region. Thus warm water forms are distributed in the shallow bottoms of the cape region, by the oceanic current.

Conclusion

An unusual oceanic condition exists in Wakasa Bay. The Tsushima current of high temperature and salinity crosses the gulf at the surface, whereas a cold water mass characteristic of the Sea of Japan occupies depths below 200 meters. Many banks at the mouth of the bay complicate the bottom configuration. These banks provide important fishing centers and are of special interest to ecologists as they are endowed with a variety of oceanic conditions and exhibit many peculiarities in the distribution of organisms. The number of species and individuals is closely related to the depth and character of the bottom.

THE LIFE AND ENVIRONMENT OF THE EARLY ORDOVICIAN SEA IN CENTRAL TEXAS[3]

by

Preston E. Cloud, Jr.[4] and Virgil E. Barnes[5]

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Introductory remarks

The following summary of facts and speculations concerning the life and environment of the early Ordovician sea in central Texas has been extracted and rearranged from sections of a report, by the writers, on the Ellenburger group of central Texas.[6] The region specifically considered is the Llano uplift, a basinlike structural uplift at the geographic center of Texas. In

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[3] Prepared under cooperative arrangement between the Geological Survey, U. S. Department of the Interior, and the Bureau of Economic Geology, University of Texas. Published with the permission of their respective directors.

[4] Geologist, Geological Survey, U. S. Department of the Interior.

[5] Geologist, Bureau of Economic Geology, University of Texas.

[6] In press, to be published as Bulletin 4621 of the University of Texas, Bureau of Economic Geology.

For description of the stratigraphic units here considered see Cloud, P. E. Jr., Barnes, V. E., and Bridge, Josiah, Stratigraphy of the Ellenburger group in central Texas - a progress report: Univ. Texas Pub. 4301, pp. 133-161, pls. 1-8, 1945.

this region about 4,400 square miles of lower Paleozoic and pre-Cambrian rocks have been exposed by doming and erosion of the overlying younger Paleozoic and Cretaceous strata. A two-year study of eight areas selected as representative of the Lower Ordovician terrane in this region furnished most of the background for the present summary discussion. More complete evidence for the conclusions given is presented in the report referred to above.

The sequence of stratigraphic units to which reference is made in the present paper is as follows; correlative units in the Ozark uplift of Missouri and Arkansas[7] being parenthetically noted:

Lower Ordovician
- Ellenburger group
  - Honeycut formation (Theodosia and Rich Fountain formations)
  - Gorman formation (Roubidoux formation)
  - Tanyard formation (Gasconade dolomite; including Van Buren strata)
    - Staendebach member
    - Threadgill member

Upper Cambrian[8]
- Wilberns formation (Eminence and Potosi dolomites, plus Elvins group)
- Riley formation (Bonneterre dolomite and Lamotte sandstone), rests on pre-Cambrian.

Lateral changes in the Ellenburger and Wilberns strata are diagrammatically shown in figure 1.

In the ensuing pages the writers first discuss the faunal elements of the Ellenburger formations, then consider the general ecologic implications of Ellenburger life, and finally speculate upon the probable ecography of the Ellenburger sea and compare it with the Late Cambrian sea of central Texas.

Fossils of the Ellenburger formations

Tanyard formation

The biota of the Tanyard formation is dominated by gastropods and cephalopods, many of them large. A dasaycladacean alga, a few brachiopods, occasional trilobites, an archaeostracan crustacean, and a fossil identified by Dr. R. S. Bassler[9] as the primitive coral Lichenaria also occur.

7/ See Cullison, J. S., Paleocological conditions in the Ozark region in Lower Ordovician (Canadian) time, this series of reports, No. 5, pp. 47-53, 1945.

8/ See Bridge, Josiah, Barnes, V. E., and Cloud, P. E., Jr., Stratigraphy of the Upper Cambrian, Llano uplift, Texas: Bull. Geol. Soc. Amer., vol. 57, 1946.

9/ Oral communication to Cloud, June 1946.

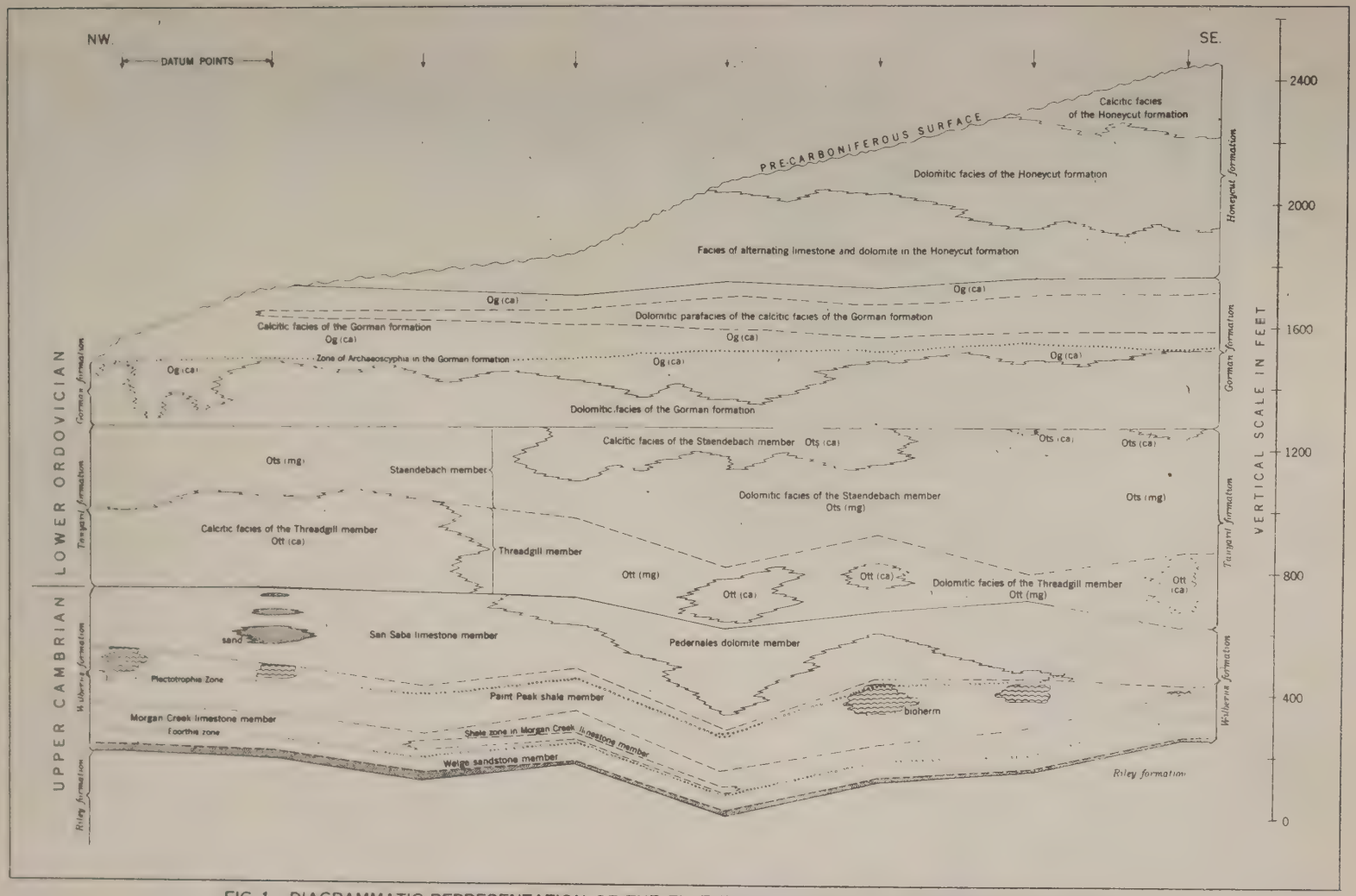

FIG. 1.—DIAGRAMMATIC REPRESENTATION OF THE ELLENBURGER GROUP AND WILBERNS FORMATION IN THE LLANO UPLIFT OF CENTRAL TEXAS

(Datum is contact of Tanyard and Gorman formations)

The gastropods Lytospira gyrocera (Roemer), Ophileta polygyrata (Roemer), and Gasconadia cf. G. putilla (Sardeson) dominate the relatively thinly bedded limestones of the Threadgill member in the western part of the Llano region. The upper 90 to 100 feet of the Tanyard formation is characterized by the dasycladacean alga Rhabdoporella,[10] two or three species of a new genus of trilobite resembling Plethopeltis, two species of the archaeostracean crustacean Ribeiria, several species of Clarkoceras, and an abundance of Ozarkina. The brachiopod Tetralobula is known only from about 40 to 50 feet above the base of the Tanyard formation in the western part of the uplift. The only other brachiopods known from the Tanyard formation are Syntrophina and Finkelnburgia, the former being rare, and the latter common. An unnamed robust species of Finkelnburgia holds a position about 260 to 285 feet above the base of the Tanyard formation in the Bear Spring area. The cephalopods Dakeoceras, Burenoceras, Levisoceras, and Conocerina make their first appearance near the middle of the Threadgill member of the Tanyard formation; with Burenoceras ranging to the middle of the Gorman formation and Conocerina ranging perhaps to the top of the Tanyard, but apparently not into the Gorman formation. Dakeoceras seems to have a shorter range, and has not been recognized above the lower one-third to one-half of the Staendebach member. Levisoceras seems to range through much of the upper three-fourths of the Tanyard formation but not to its top. Ectenoceras ranges downward from the top of the Tanyard formation to some point well below its middle. Oneotoceras is rare but diagnostic of the Tanyard formation. It has been seen almost at the top of the formation and at points well toward or below the middle. Lytospira (formerly confused with Ecculiomphalus), although typically a fossil of the Threadgill member in the western part of the Llano uplift, ranges across the Tanyard-Gorman boundary and perhaps well into the Gorman formation. Although Ophileta ranges through the Tanyard and Gorman formations and into the Honeycut, the Tanyard species are commonly large and relatively depressed, both as to spire and cross-section of the whorl. Sinuopea and Schizopea range through or almost through the Tanyard formation and downward into the top of the Cambrian, but are most abundant in the Tanyard. Ozarkina and "Helicotoma" of the type of "H", uniangulata (Hall) range from the top of the Tanyard formation to somewhere well below its middle, and Gasconadia ranges from its base to somewhere above the middle. Chepultepecia ranges through at least the upper half of the Tanyard and into the Gorman formation. Patelliform snails, and the so-called "Pelagiella" paucivolvata (Calvin) are locally abundant. The patellids range through the formation, but the range of "P". paucivolvata has not been determined. A "Euconia"-like snail has been seen at a few places. Leiostegium occurs in the lower part of the Tanyard formation at some localities. Cystid and chiton plates are locally common.

Gorman formation

The Gorman formation is not only poorer in number and variety of fossils than the other formations of the Ellenburger group, but proportionately fewer of its fossils have been described. Its most striking faunal elements are the large gastropods "Roubidouxia" and Lecanospira, but a number of other gastropods and cephalopods, a few brachiopods and trilobites, and a sponge are known.

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[10] Determined by J. Harlan Johnson, letter to Barnes, 10/29/45.

"Roubidouxia" (of the type of "R". umbilicata Ulrich and Bridge) occurs from the base to the top of the Gorman formation and its sure identification probably constitutes proof of a Gorman age. Lecanospira is known only from the Gorman formation. It ranges from the top of the formation probably to its base but is uncommon in the basal strata. Lytospira and Ophileta are known from the Gorman formation but are not characteristic of it. Ophileta, or Ozarkispira, of the type of O. rotuliformis or O. leo, however, suggest the Gorman formation, and in general the post-Tanyard ophiletas have higher spires and relatively deeper whorls than do the Tanyard species. Patelliform gastropods are locally common. Some belong to the genus Proplina, but the generic assignment of others is uncertain. Chepultepecia is not uncommon in the lower part of the Gorman formation, although its presence tends to suggest the Tanyard. The high-spired gastropod Hormotoma makes its first known appearance at the base of the Gorman and extends through the Honeycut formation. Plethospira also first appears in the Gorman formation, and perhaps Raphistomina and Polhemia. Two species of the brachiopod Diaphelasma mark the upper 90 feet of the Gorman formation and Syntrophina suggests the lower 120 feet of the Gorman, although one Syntrophina has been found about 200 feet below the Tanyard-Gorman boundary. Syntrophinella is known only from the vicinity of the Gorman zone of Archaeoscyphia, the latter fossil being a sponge known below the Honeycut formation only from a restricted interval near the middle of the Gorman formation. A few cephalopods are known from the Gorman formation, but most of these have not been identified. The flat-ended siphuncle of Mcqueenoceras occurs locally in the upper half, a large Clitendoceras-like cephalopod occurs in the zone of Archaeoscyphia, and small strongly curved breviconcs having flaring aperatures and ranging from the zone of Archaeoscyphia to the base of the formation are assigned to Burenoceras. The piloceratids are represented only by a single specimen close to Piloceras hornei Ulrich, Foerste, and Miller, which was obtained 15 to 20 feet below the Gorman zone of Archaeoscyphia. Of trilobites, species of Hystricurus are most common, but the genus ranges into the Tanyard formation also. An occasional cystid plate represents the pelmatozoans.

Honeycut formation

Many of the Honeycut fossils of central Texas appear to be specifically identical with fossils described from the Jefferson City formations of Missouri by Cullison.[11] The dominant faunal elements are the sponge Archaeoscyphia annulata Cullison, species of the gastropod operculum Ceratopea, and species of gastropods Orospira, Hormotoma, and other gastropods of many sizes and shapes. Species of the trilobites Jeffersonia, Rananasus, and Bathyurellus are common at places in the lower half of the formation, with Rananasus apparently having a fairly restricted range. Siphuncles of the endoceratid cephalopod Mcqueenoceras are also locally common.

11/ The Stratigraphy of some Lower Ordovician formations of the Ozark Uplift: Univ. Missouri, School of Mines and Met., Bull. Tech. Ser., vol. 15, no. 2, 1944.

Except for its occurrence near the middle of the Gorman formation, Archaeoscyphia is known only from the lower half of the Honeycut, but it is there very abundant locally. No specimen has been seen in the position of growth, but occasional joined specimens and their local concentrations suggest that these sponges grew in colonies from a common substratum. The brachiopod Xenelasma is known from the lower 140 feet of the Honeycut formation and is common in the lower 70 feet. Mostly it occurs in chert, but it is very common as free silicified specimens at places on the top surface or in the top inch or two of the highest stratum of the Gorman formation. It is not known at a lower position, and the "Gorman specimens" probably grew at the sea-floor of earliest Honeycut time. Tritoechia has been found at a few places in the Honeycut formation, and, of course, Finkelnburgia has also been noted. Six "species" of Ceratopea have been recognized, and found to characterize particular parts of the section. These are at present designated by numbers, pending description and naming of the new species. Species 5 and 6 (C. "keithi" Ulrich) each display several varieties, and the young of species 3 (C. robusta Oder) are so difficult to tell from species 2 (C. canuliformis Oder) that the two forms may have to be regarded as varieties of the same form. In addition to the six species of Ceratopea noted, Ceratopea cf. C. tennesseensis Oder has been collected from the highest Honeycut stratum known in the Llano uplift and a small horn-shaped form is known from the lower part of the formation. "Maclurites affinis Billings" (of authors) has been found only from about 130 to 180 feet above the base of the Honeycut. This planispiral, hyperstrophic or pseudosinistral gastropod is easily confused with Lecanospira and possibly represents a new sub-genus or genus intermediate between Maclurites and Lecanospira. A marked bulge on the inner surface of the whorl is a distinguishing feature, allying it to Maclurites. Raphistomina, Leveurilla, Polhemid, Plethospira and patelliform gastropods occur locally and a sinistral gastropod resembling Onychochilus was seen at one place. The coiled cephalopod Tarphyceras cf. T. chadwickense Ulrich, Foerste, Miller, and Furnish has been found between 280 and 400 feet above the base of the Honeycut formation, representing an extension of the genus Tarphyceras into younger beds than it has previously been reported from. Piloceratid cephalopods are represented by the occurrence of Allopiloceras at three localities having a range of 460 to 580 feet above the base of the Honeycut formation. Cotteroceras or a laterally compressed Cyptendoceras was seen at a few places. Aphetoceras and Moreauoceras have been collected from the lower part of the Honeycut formation. The archaeostracan crustacean Eopteria has been found only from about 130 to 180 feet above the base of the Honeycut formation, holding essentially the same range as was observed for "Maclurites affinis."

Ecologic implications of Ellenburger life

Except locally the fossil assemblages of the Ellenburger rocks are few in number of species and individuals. The faunas are dominantly molluscan, with gastropods and cephalopods relatively well represented. Brachiopods are few in number, only 7 genera and 12 or 14 species being known from the entire 1,800 feet of rocks that comprise the Ellenburger group. Trilobites are uncommon, but better represented than the brachiopods. Two genera of archaeostracan crustaceans and two of sponges are known, and a fossil identified by Dr. R. S. Bassler as the primitive coral Lichenaria occurs near the top of the Tanyard formation. Representatives of other zoologic groups are rare or absent.

Evidence of plant life is limited to stromatolites,[12] possibly related to the activities of sediment-binding algae,[13] and in the upper part of the Tanyard formation, abundant remains of the dasycladacean alga Rhabdoporella. The ecologic implications of the algal structures are discussed in the papers cited, and are summarized in a later section of the present paper.

In their dominantly molluscan aspect the Ellenburger faunas recall those of correlative carbonate rocks in the Ozark uplift and the southern Appalachian region and differ from those of the Arbuckle and Wichita Mountains, the Marathon Basin, and to a lesser extent the Franklin Mountains. They are, of course, markedly different from those of the Lower Ordovician black shale and clastic facies.

The Ellenburger fossils have not been studied in sufficient detail to say whether or not they occur in definite zones separated by unfossiliferous rock as Cullison[14] found the Lower Ordovician fossils in the Ozark uplift to do. Some species and genera certainly mark particular zones, but it is the impression of the writers, based on mapping, that the fossils in general are erratically and sparingly distributed through much of the section. The impression is gained that, although conditions were in general not favorable to the shell-bearing bottom-dwellers, there were local areas at most times where benthonic shells could and did survive. At some times these conditions were more widespread and relatively abundant life developed, but it is believed that in most instances this more abundant life was an outgrowth from forms that held on through the unfavorable periods. An analogy is found with conditions on the Bahama Banks today, where a generally soft bottom and waters periodically muddied with flocculent calcium carbonate are unfavorable to most forms of life, but where local patches of solid bottom support a rich molluscan fauna, as well as sponges, corals, and calcareous algae.[15]

Mud-ingesting organisms were active through most of Ellenburger time, as is shown by the commonly pelleted limestones.[16] These pelleting organisms apparently were mostly soft bodied, for the shell-bearing benthos, allowing

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[13] Black, Maurice, The algal sediments of Andros Island, Bahamas: Roy. Soc. London, Phil. Trans., ser. B, vol. 222, pp. 165-192, figs. 1-16, pls. 21-22, 1933b.

[14] 1945, op. cit., pp. 47, 52.

[15] Black, Maurice, The precipitation of calcium carbonate on the Great Bahama Bank: Geol. Mag., 70, pp. 455-466, 1933a.

[16] Moore, H. B., Faecal pellets from marine deposits, Cambridge University, Discovery Reports, vol. 7, pp. 17-26, 1933.

Moore, H. B., Faecal pellets in relation to marine deposits, Recent Marine Sediments, publ. by Amer. Assoc. Petr. Geol., Thomas Murby and Co., London, ed. by Parker D. Trask, pp. 524, fig. 1, 1939.

[12] Cloud, P. E., Jr., Notes on stromatolites: Amer. Jour. Sci., vol. 240, pp. 363-379, fig. 1, pls. 1-2, 1942.

that preserved shelly remains are probably but a small representation of their original total, are insufficiently represented to account for the numbers of animals that must have engaged in the pelleting process. Probably many of them simply plowed up and ingested the surface muds, but others actually bored into the muds and left well defined burrows. Moore[17] believes that the simple ovoid pellets, such as are most common in the Ellenburger rocks, "are those of either polychaetes (worms) or mollusks." Thus, if the inference is correct that the Ellenburger pellets were mostly made by soft bodied organisms, worms may have been responsible for them.

Tracks of fossils are common in the relatively thinly bedded limestones of the Threadgill member of the Tanyard formation in the western part of the Llano region. Most of these are discontinuous, selectively dolomitized welts which average about as broad as the apertural diameter of the common snails of the same beds [Lytospira gyrocera (Roemer), Ophileta polygyrata (Roemer)]. They are restricted to the surface of the rock and thus are not borings. Commonly they seem to anastomose because of overlapping. Their discontinuous nature suggests that they were made by some buoyant benthonic organism that from time to time lost contact with the sea bottom due to surging of the waves. This, in connection with their size and their association with the common snails of the time strongly suggests that they are the trails of Lytospira and Ophileta. The ancient snails, like the modern ones, doubtless secreted an agglutinating substance along the paths they followed, and this would serve to bind and localize the drifting coarser sediments of the time and encourage the selective dolomitization seen. The interruption of the trails suggests that they were made within reach of the surging action of the waves and probably indicates reasonably shallow waters.

At one place, in the same beds that display the common type of trail, a corrugated trail about one-third of an inch wide and 12 inches long suggests trails that have been attributed to trilobites, and trilobites occur in the bed on which the trail was found. Several broader, bifurcating trails that occur in these beds are more difficult to assign. They could have been made by cephalopods, resting suspended but in contact with the sea-floor and washing back and forth with the surging of the waves.

Evidence of possible nektonic organisms in Ellenburger rocks is limited to a few conodonts from the lower Tanyard strata of the Threadgill Creek section, in the southwestern part of the Llano uplift.

Probable ecography of the Ellenburger sea

1. Ellenburger waters were marine. They supported many forms of life unknown except from marine environments and none that are known to be limited to fresh waters.

2. The Ellenburger province of the mid-Continent sea was shallow. Its bottom was less than 100 fathoms deep, probably at most times and places less than 15 and possibly less than 5 fathoms deep, and perhaps locally awash. The

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17/ 1933, op. cit., p. 25.

environment was thus wholly neritic and possibly at times and places littoral, the terms neritic and littoral as here used referring to depth of water without implying any particular relationship to the principal shore- areas of the times.

The intermittent presence of structures formed through the agency of algae (stromatolites) suggests a maximum possible depth of about 100 fathoms and their local good development favors a depth of less than 15 fathoms.[18] However the depth of optimum photosynthesis was probably reduced by intermittent turbidity, resulting from the stirring up of calcium carbonate. Therefore, beds containing large and abundant stromatolites may have been deposited in waters considerably less than 15 fathoms deep. Black[19] shows that colonies of sediment-binding algae that are now building structures comparable to the common stromatolites of the Ellenburger actually have their optimum development in tidal flats, or above normal high tide, on near-shore flats that are periodically inundated by marine waters.

Evidence that the sea-bottom was affected by the surging action of waves is indicated by interrupted gastropod trails in the lower Tanyard rocks and the occasional development of ripple-marks throughout the section. The local occurrence of polygonally cracked limestones suggests temporary subaerial exposure, which may have occurred in mud-flats of the littoral zone between tides or even at higher levels. The local development of intraformational breccias or conglomerates, commonly in association with sands thought to be wind-borne, suggests waters sufficiently shallow to develop strong bottom turbulence during periods of storm. The great development of chemically precipitated carbonate muds from which the Ellenburger rocks were probably formed presupposes an environment of warm shallow waters; and the only known comparable sedimentary area in recent seas, the Bahama Banks, is mostly less than 3 fathoms deep, and apparently does not exceed 5 fathoms in depth except on its shelving margins. If the temperatures of Ellenburger times were high enough and the circulation of the sea poor enough, the carbonate sediments might have settled undissolved through waters deeper than those in which flocculent carbonate minerals could survive in present seas. It is therefore not possible to place an average depth shallower than the 15 fathoms thought to be required for optimum photosynthesis, and even depths this shallow cannot be proved for beds in which stromatolites do not thrive.

3. The water of the Ellenburger sea was warm, and so, probably, was the air above it. Tropical or semitropical conditions are strongly indicated by the great succession of chemically precipitated carbonate sediments from which the Ellenburger rocks were probably derived.

The evidences of primarily chemical deposition, and the general absence of clastic fabrics, suggests that the lime-muds of Ellenburger time may have been much more rapidly and abundantly precipitated than those of the Bahama Banks. This might suggest that the waters that moved into the Ellenburger

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18/Cloud, 1942, op. cit., pp. 370-371.

19/1933b, op. cit.

province of the mid-Continent sea were more highly supersaturated with calcium salts, and that conditions affecting the precipitation of $CaCO_3$ were more persistent or more accelerated than they are over the Bahama Banks today.

The known representatives of Ellenburger life do not furnish critical evidence on the temperature of the waters of Ellenburger time. Although lime-secreting algae seem generally to grow better in warm water than in cold water, they actually have a wide thermal range and do not of themselves furnish direct information about the temperatures under which they lived.[20] On the basis of numbers and variety alone the Ellenburger fauna does not compare at all well with the warm-water fauna of the present seas, except those found in unusual environmental circumstances such as occur on the Bahama Banks.

4. Ellenburger waters were probably well oxygenated.

Their dominant faunal elements are relatively large and thick-shelled gastropods and cephalopods. Intraformational conglomerates and breccias associated with probably wind-borne sands, and the surging indicated by ripple marks and interrupted gastropod trails, suggest intermittently turbulent conditions extending to the shallow sea-floor. Chemical analyses of Ellenburger rocks show them to be persistently low in iron away from places where it could have been secondarily introduced.

5. The Ellenburger sea was intermittently turbulent and at such times was probably "milky" with flocculent lime-muds stirred up from the bottom.

The opacity of the waters at such times doubtless inhibited the formation of structures dependent for their origin on photosynthetic activity (stromatolites), and probably was unfavorable to the shell-bearing benthos as well.

6. At most times and places the bottom of the Ellenburger sea was soft.

The patchy and intermittent occurrence of fossils in the Ellenburger, except in the lower beds at the west side of the Llano region, suggests a generally soft bottom, inhibiting the development of the shell-bearing benthos except at the few places where firm bottom conditions prevailed. The probable nature of the original sediments comparable with those of the Bahama Banks, suggests a similar conclusion.

7. The sea in which the lower Tanyard sediments accumulated probably had a firmer bottom on the west side of the Llano region than it did to the east.

The abundance of large gastropods in the limestones of the Threadgill member on the west side of the Llano uplift suggests this. The evidence of wave surging indicated by ripple marks and interrupted gastropod trails shows that the water here was still fairly shallow, but the probably firmer conditions indicated suggest that it was marginal to, if not wholly to the west of the areas of most active sedimentation. This point is supported by the

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20/ Cloud, 1942, op. cit., pp. 369-370.

fact that the Tanyard formation is thinner on the western side of the Llano uplift than it is at the east.

8. In Ellenburger time land lay to the east and south of the Llano region. This land was either nearly level, relatively far removed, or separated from the Llano region by a channel. The sea-floor was probably shallowest at the east and south sides of the Llano region and deepened gradually to the northwest.

Land to the east and south is indicated by the fact that the disseminated, well-rounded, frosted and wind-borne sands of the post-Tanyard strata become more numerous and volumetrically more important to the east and south. That it was either nearly flat, relatively far distant, or separated from the Llano region by a channelway is indicated by the absence from the Ellenburger of recognizable water-borne detritus; and the first alternative is eliminated for Tanyard and most of Honeycut time by the distribution of wind-borne detritus. Deepening of the sea westward and northward is indicated by a general decrease in dolomite in this direction. It has been noted that rocks that are dolomites in or towards the ancient shoal waters tend to grade seaward to limestones, concomitantly with increase in depth and thus decrease in temperature of the bottom waters.

9. If the land that lay to the east and south of the Llano region was not nearer to the present margins of the Llano region in Gorman time than it was in Tanyard time and much of Honeycut time, then atmospheric turbulence was at its peak in Gorman time.

This assumption is based on the virtual absence of sand from the outcropping Tanyard rocks and the fact that it is commoner and more abundant as disseminated, frosted grains in the Gorman formation than in the Honeycut. In the southeastern part of the region (Johnson City area) evidence of marine (thus atmospheric) turbulence was observed to be commoner in the Gorman formation than in the beds above and below it. Evidence on this point from other parts of the Llano uplift is more equivocal, but either in support of or at least not in conflict with observations from the southeastern part of the region.

10. Variations in the depth and temperature of the Ellenburger sea were probably slight, but such surely occurred.

Inasmuch as dolomitization is probably favored by elevated temperatures, and temperatures of water ordinarily decrease with depth, penecontemporaneous dolomites may indicate shallower, warmer waters at the time of their formation than do limestones. The later diagenetic dolomites suggest warming of the bottom somewhat after deposition and at least partial compaction of their source sediments.

A marked feature of the Honeycut formation is the thinly alterrating sequence of limestones and dolomites that characterizes its lower part. These suggest the inception of fluctuating disequilibrium in the sea after a long period of relative stability in late Gorman time. This condition of instability may have taken the form of simple fluctuations in depth and temperature,

or it may have been related to more complex conditions related to the physical chemistry of sea water (such as pH and ionic interactions). In any event variations in temperature and depth probably had some effect on the dolomitization process, in the direction indicated.

It should be mentioned that A. E. Parr[21] has described how inclosed saline waters under certain conditions may be flooded and covered with fresh waters from the land and heated up much in the manner that the air in a greenhouse is warmed by the sun. According to Parr, data from one such inclosed area on the coast of Norway showed a temperature of 16°C. higher at 2 meters below the surface than at the surface, and at some places along the coast of Norway the growth of oysters is fostered by such "hot-house effects." Periodic repetition of some such mechanism acting on sluggish waters could explain rythmic dolomitization as well as variations in depth of water alone. But, again, shallowness of water would probably facilitate the process, and the prolonged overspread of a fresh-water cover on shallow saline waters would probably produce optimum conditions for elevated temperatures and penecontemporaneous or secondary dolomitization.

11. Although variations in the general types of life that dwelt in the Ellenburger sea are not marked, stratigraphically significant faunal variations in the Ellenburger rocks are apparent. The stratigraphically significant faunal changes that can be correlated with similar changes in distant regions probably are related to eustatic changes.

At most places fossils are markedly more abundant in Tanyard and Honeycut strata than they are in the Gorman formation. The most conspicuous difference in general faunal aspect is the relative abundance of sponges and trilobites, and the dominance of heavily operculated gastropods (Ceratopea) in the Honeycut formation. The stratigraphically marked faunal changes at the Tanyard-Gorman and Gorman-Honeycut boundaries correlate with faunal changes that are widespread in North America. They, therefore, must mark some widespread change.

Eustatic changes, that is movements of the ocean bottom itself, affecting the volume of water on the continents and the depth of water in entire epicontinental seas,[22] or changes in the total volume of ocean waters; are a logical vehicle for accomplishing widespread changes. Contraction of the epicontinental seas doubtless affected climatic conditions, and this, plus concomitant changes in depth and salinity could affect extermination of the faunas from the regions occupied by shallow seas without requiring prolonged subaerial exposure, and perhaps without subaerial exposure at all. Repopulation would follow marine reinvasion, and if environmental conditions were similar to those previously existing, faunas of generally similar but taxonomically different aspect should result.

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[21] Oral communication to Cloud, Nov. 1, 1938.

[22] Grabau, A. W., Principles of Stratigraphy (2d. ed.), A. G. Seiler, New York, 1924.

In the Llano region, the Ellenburger sea was probably so shallow that it was actually exposed to the atmosphere at the time of negative eustatic changes (Tanyard-Gorman and Gorman-Honeycut boundaries). Perceptible truncation was not accomplished because atmospheric agencies were not adequate to affect the wide low-lying mud-flats, and because the waters of the shallow reinvading epeiric sea were probably sluggish except at times of strong atmospheric disturbance.

12. Although conditions in general, during Ellenburger time, were not favorable to the shell-bearing bottom-dwellers, there were probably at most times local areas where benthonic shells could and did survive. At some times favorable conditions were more widespread in the region and relatively abundant life developed, but it is believed that in most instances this was an outgrowth from forms that held on through the unfavorable periods. Analogy with conditions on the Bahama Banks suggests that survival was in large part related to firmness of the bottom.

A different conclusion is reached by Cullison[23] to account for the apparently intermittent character of the Lower Ordovician faunas of the Ozark uplift. He reasons that successive faunal invasions from somewhere beyond the Ozark region were perhaps related to eustatic changes. However, the eustatic changes postulated do not appear to have been closely reflected in other regions except in a few instances (the major faunal boundaries).

13. Even though the shell-bearing benthos may have been rare during much of Ellenburger time, the abundant presence of soft-bodied organisms is indicated by the abundance of pelleted areas in the limestones.[24] This bears directly on the potentialities of the carbonate rocks of the Ellenburger group as source sediments of petroleum.

The almost self-evident conclusion that "the more organic matter a recent marine deposit contains the greater are its chances of being a potential future source of petroleum" was reaffirmed by Trask as a result of extensive studies by himself, Hammar, and Wu.[25] In view of their probably extensive mud-ingesting fauna, it is no longer safe to regard the Ellenburger strata as an unlikely source of petroleum where they are not in a position to receive leakage from above.

14. The only known area of recent sediments that can be compared closely with those from which the Ellenburger rocks were theoretically derived is the

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[23] 1945, op. cit., p. 52.

[24] Moore, loc. cit.

[25] Origin and environment of source sediments of petroleum, Gulf Publishing Co., Houston, Texas, 1932.

Bahama Bank region. If the Llanoria channel of the Ouachita trough[26] extended to the east and south of the Llano region as early as the beginning of Ordovician time, the Ellenburger sediments may actually have been separated from the mainland by a relatively deep channel. In that event the Llano region would have formed a submarine bank, deepening gradually to the west, and with shoals and perhaps tidal flats or even local island areas at the south and east margins, as Andros Island lies on the bank of the tongue of the ocean.

Whatever happened at the south and east, it is doubtful if the seabottom dropped off steeply to the west and north, or to great depths on any side. That the Llano region could have been a structural as well as a sedimentational counterpart of the Bahama Banks in Ellenburger time is suggested by its positive structural history, but the known sedimentary evidence from the surface and from the subsurface to the north reveals no features in this direction that could be interpreted as the margins of an abrupt bank. However, thinning and increasing calcicity along the west side of the southern end of the Bend arch suggests that there may have been a westward steepening in pitch of the bottom profile essentially coincident with the crest of the present-day Bend arch.

The writers have misgivings about what actually lay immediately adjacent to the Llano region at the south and east. Were the Llanoria channel of the Ouachita trough not a well documented feature of later times, and were it not indicated to be so suggestively like the narrow channels that separate the Bahama Banks from Florida and Cuba[27] they might have guessed that the Ellenburger sea graded directly to a peneplained hinterland in these directions.

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[26] Sellards, E. H., Rocks underlying Cretaceous in Balcones fault zone of central Texas: Bull. Amer. Assoc., Petr. Geol., vol. 15, no. 7, pp. 819-827, fig. 1, 1931.

Sellards, E. H., The pre-Paleozoic and Paleozoic systems in Texas, in the Geology of Texas, Vol. 1, Stratigraphy, Part 1: Univ. Texas Bull. 3232, pp. 15-238, 1932.

Miser, H. D., Relation of Ouachita belt of Paleozoic rocks to oil and gas fields of mid-continent region: Bull. Amer. Assoc. Petr. Geol., vol. 18, pp. 1059-1077, figs. 1-5, 1934.

DeFord, R. K., and others, West Texas-New Mexico symposium; Index map: Bull. Amer. Assoc. Petr. Geol., vol. 24, pp. 2-3, 1940.

[27] Drew, G. H., On the precipitation of calcium carbonate in the sea by marine bacteria, and on the action of denitrifying bacteria in tropical and temperate seas: Carnegie Inst. of Washington, Pub. 182, Papers from the Tortugas Laboratory, vol. 5, pp. 7-45, figs. 1-4, charts A-B, 1914.

Even a flat and distant hinterland, however, does not explain the remarkable scarcity of terrigenous debris in the Ellenburger so well as would the presence of a current swept channel between the Ellenburger shoals at the north and west and land to the south and east.

Comparison of the Ellenburger sea with the Late Cambrian sea of central Texas

Schuchert's maps of Late Cambrian and Early Ordovician time[28] show the epicontinental seas and channel ways of those two times to have had very similar patterns. It seems unlikely that Schuchert's "Ouachita trough" extended west as far as it is shown in Late Cambrian time, but in central Texas the general position of the shore lines was probably close to that shown.

We are principally interested, at this place, in evidence that may bear inferentially on actual differences between the environment of the Cambrian waters and those of the Ellenburger sea. In contrast to those of the Ellenburger, the Upper Cambrian faunas are dominated by trilobites, with brachiopods locally abundant and with gastropods rare except at places in the higher carbonate rocks. The Cambrian rocks are dominated by sandstone, detrital limestone and shale. Stromatolitic limestones are locally well developed, and the upper carbonate rocks are finer grained and more typically dolomitic in the eastern part of the Llano uplift than in the west. The stromatolitic limestones are commonly microgranular to sublithographic and ordinary limestones of the upper part of the Wilberns formation are not uncommonly sublithographic in the more easterly exposures. Glauconite occurs abundantly to sporadically in the granular limestones of the Upper Cambrian strata; but macroscopically visible glauconite is apt to be absent or much reduced in quantity in the microgranular to sublithographic limestones, the noncalcareous sandstones, and the shales.

Inference from these facts results in the conclusion that the environment of the late Cambrian seas differed from that of the Ellenburger sea in several important respects.

Of course the fossils and the presence of glauconite show that the Cambrian sea was definitely saline, except possibly at the time the lowest Riley sediments were being deposited. The general presence of glauconite, if inferences based on study of an extensive literature are valid, suggests that, for the most part, the bottom of the sea in which the Upper Cambrian sediments accumulated was deeper, colder, and less well oxygenated than that in which the Ellenburger beds were formed. If the inferences of E. W. Galliher[29] are

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[28] Schuchert, Charles, and Dunbar, C. O., A Textbook of Geology. Part II, Historical Geology (4th ed.), John Wiley and Sons, Inc., New York, 1941.

[29] Glauconite genesis: Bull. Geol. Soc. Amer., vol. 46, pp. 1351-1366, fig. 1, pls. 109-110, 1935a.

Geology of glauconite: Bull. Amer. Assoc. Petr. Geol., vol. 19, pp. 1569-1601, figs. 1-16, 1935b.

Biotite-glauconite transformation and associated minerals: Amer. Assoc. Petr. Geol., Recent Marine Sediments, pp. 513-515, fig. 1, 1937.

valid, it also suggests the presence of igneous or micaceous metamorphic rocks on near by coasts or islands. Such islands, incidentally, are known[30] to have been present at least as late as middle Riley time. The continued or intermittent presence of a large island or other land mass directly west of the Llano region, almost if not quite to the end of Cambrian time, is indicated by the locally thick water-borne sands near the top of the Wilberns formation in the western areas. The waters adjacent to this land mass were probably deeper than those to the east and it may not have been a principal or persistent shore region.

That the waters of the late Cambrian sea were intermittently shallow and probably relatively warm in later Wilberns time is indicated by the intermittent occurrence of prominent stromatolitic bioherms and biostromes in the upper two-thirds of the Wilberns formation. The highest Cambrian strata show a rising proportion of sublithographic, sparingly glauconitic to nonglauconitic limestones as they are traced eastward. This suggestion of increasing chemical precipitation combines with the increased dolomitization eastward to indicate that the principal shoal-area of the times, at least of latest Cambrian time, lay to the east. A general shoaling of the Cambrian seas toward the end of Cambrian time is suggested. The eastern part of the Llano region was above wave base, and possibly above water, for a long enough time at the end of the Cambrian to permit considerable truncation of Cambrian sediments in the southeastern part of the region and lesser truncation elsewhere. In the western part of the region sedimentation was probably continuous across the Cambrian-Ordovician boundary; and the eustatic effects, with subsequent environmental changes, may be called upon to explain the faunal break at this place.

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[30] Bridge, Barnes, and Cloud, op. cit.